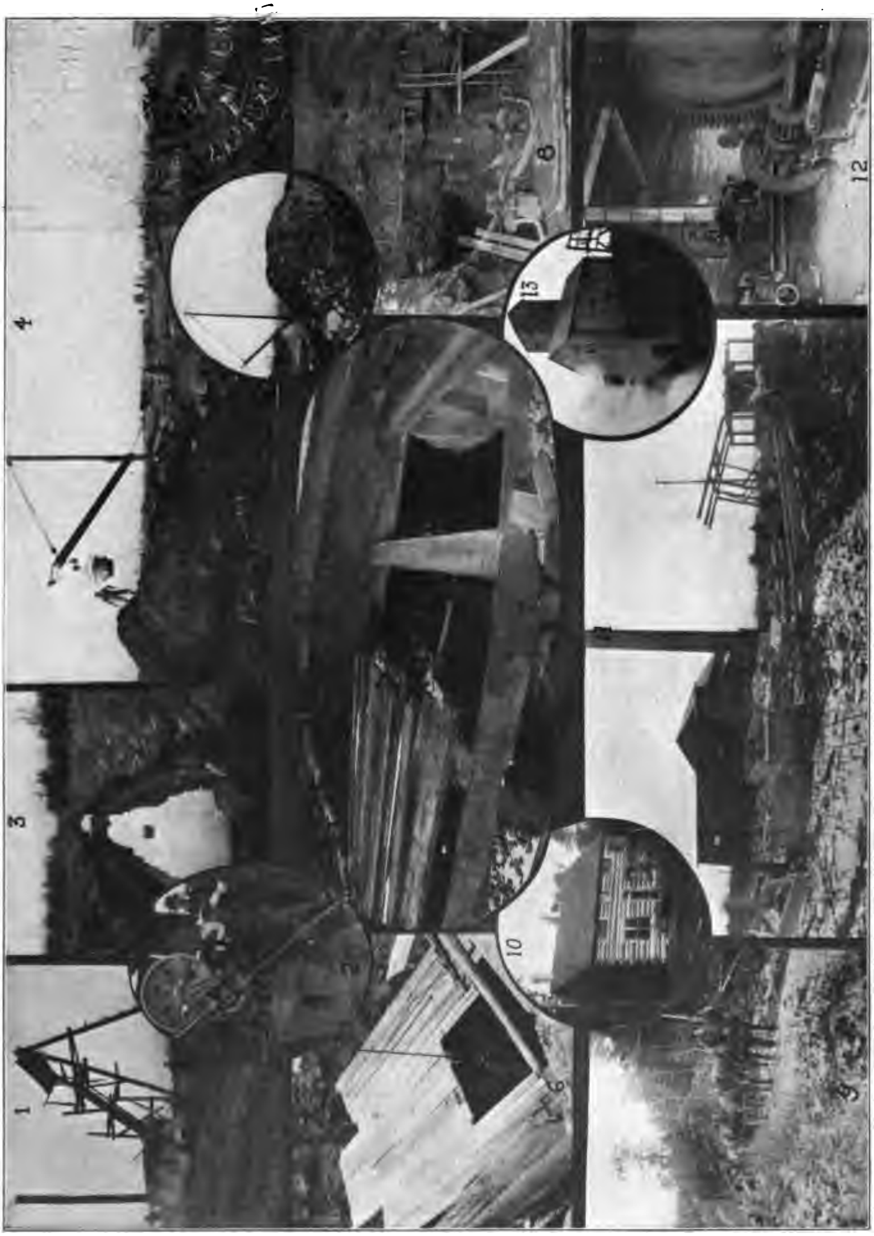
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## HOW LAKE SUPERIOR MINES ARE OPENED.

No. 1 and 2.—Diamond Drill Exploration.

3.—Trench Crosscut Exploration.

4.—Starting Pit in Sand for Permanent Shaft.

5.—Bottoming Pit in Gravel and Boulders at Bed Rock.

6.—Diamond Drilling in Lode from Bottom to Pit, to determine Dip.

7.—3-Compartment Shaft from Surface (Note Outline of Pit.)

8.—Starting Shaft in Lode at Bed Rock (Looking down at Angle of 36°.)

9.—Hauling Development Machinery to New Location in Keweenaw Woods.

10.—Company Office and Engineers' Quarters.

11.—Power Plant completed and Shaft House started.

12.—Development Machinery Ready for Service.

13.—Permanent Shaft Rock House in Service.

All of the pictures in this series were taken within a period of two weeks on various Calumet & Hecla properties with the exception of the company office (Keweenaw) and permanent shaft rock house (Champion). This shows in only a moderate degree the extensiveness of the Calumet & Hecla's present exploratory and development work.

# PROCEEDINGS

OF THE

# Lake Superior Mining Institute

TWELFTH ANNUAL MEETING

HELD IN THE COPPER COUNTRY, WITH HEAD-QUARTERS AT HOUGHTON, MICH.

AUGUST 8th, 9th and 10th, 1906.

VOL. XII.

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AT THE OFFICE OF THE SECRETARY,
1907.

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ISHPEMING, MICH.

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For Year Ending August, 1906.

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(The Above Officers Constitute the Council.)

---

Following officers were elected at the annual meeting, August 9th, 1906: President, (one year) Thomas F. Cole, Duluth Minn. Vice-Presidents, (two years) David T. Morgan, Republic, Mich.; D. E. Sutherland, Ironwood, Mich.; Norman W. Haire, Houghton, Mich. Managers, (two years) J. W. Amberg, Chicago, Ill.; Pentecost Mitchell, Duluth, Minn. John C. Greenway, (one year) Hibbing, Minn. Treasurer, (one year) E. W. Hopkins, Commonwealth, Wis. Secretary, (one year) A. J. Yungbluth, Ishpeming, Mich.

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PASCOE, WILLIAM.................................Republic, Mich.
PEACOCK, D. C.......................................Hibbing, Minn.
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PENTON, JOHN A..............Iron Trade Review, Cleveland, Ohio.
PERKINS, SAMUEL J.............................Ironwood, Mich.
PERSONS, GEORGE R...........................Ishpeming, Mich.
PETERSON, JOHN O.................................Winona, Mich.
PHILLIPS, W. G.......................................Calumet, Mich.
PIPER, JAMES.......................................Negaunee, Mich.
PITKIN, S. H..............................................Akron, Ohio.
PLATTO, FRANK.....................................Ishpeming, Mich.
POLLOCK, CHARLES S...care Standard Oil Co. Minneapolis, Minn.
POPE, GRAHAM.......................................Houghton, Mich.
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QUIGLEY, G. J.........................................Kaukauna, Wis.
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SCADDEN, FRANK...........................Crystal Falls, Mich.
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SCOTT, D. D.......................................Houghton, Mich.
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SHEA, J. D............. ...........................Bessemer, Mich.
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SHELDEN, GEORGE R...care C. H. Bradley, Jr. & Co., Pittsburg, Pa.
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TUFTS, JOHN W.............Goodyear Rubber Co., Milwaukee, Wis.
TURNER, SCOTT.................316 Franklin Ave, Lansing, Mich.
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UNSICKER, WALTER...............................Bessemer, Ala.
UREN, WILLIAM J....................7 Second St., Calumet, Mich.

VALLAT, BENJAMIN W............................Virginia, Minn.
VANDEVENTER, JOSEPH..........................Ishpeming, Mich.
VAN DYKE, W. D................................Milwaukee, Wis.
VAN EVERA, JOHN R.............................Marquette, Mich.
VAN MATER, J. A..............................Puluaski, Virginia.
VAN ORDEN, F. L...............................Houghton, Mich.
VAN ORDEN, MATHEW.............................Houghton, Mich.
VAN VALKENBURG, ALLEN J.....................Abbottsford, Wis.
VAUGHN, S. H...................26 Mitchell Bldg., Milwaukee, Wis.
VOGEL, F. A.....................................Florence, Wis.

WADE, JEPTHA H....................Wade Bldg., Cleveland, Ohio.
WAGNER, JOHN M................................Houghton, Mich.
WALKER, ELTON W...............................Tombstone, Ariz.
WALL, JAMES S.................................Iron River, Mich.
WALLACE, GEORGE...............................Marquette, Mich.
WARE, JOHN FRANKLIN................128 Park St., Dayton, Ohio.
WARD, E. T.........................183 14th St., Milwaukee, Wis.
WARREN, O. B..................................Hibbing, Minn.
WARRINER, S. D................................Wilkesbarre, Pa.
WATSON, CHARLES H.........................Crystal Falls, Mich.
WEED, LOUIS B.................................Hibbing, Minn.
WELDEN, JAMES WALTER, JR.......................Ironwood, Mich.
WELLS, PEARSON................................Ironwood, Mich.
WELSH, NORVAL J. E..........................San Antonia, Texas.
WESSINGER, W. E..................610 Wolvin Bldg., Duluth, Minn.
WEST, WILLIAM J...............................Hibbing, Minn.
WHITBURN, HENRY...............................Bessemer, Mich.
WHITE, PETER..................................Marquette, Mich.
WHITE, WILLIAM................................Buhl, Minn.
WHITEHEAD, R. G...............................Amasa, Mich.
WHITING, S. B.................................Swampscott, Mass.
WILKINS, WILLIAM..............................Ashland, Wis.
WILLIAMS, JAMES H.............................Ishpeming, Mich.
WILLIAMS, THOMAS H............................Ely, Minn.
WILLIAMS, HERBERT H...........................Marquette, Mich.
WILLMOTT, ARTHUR B.......................Sault Ste. Marie, Ont.
WINCHELL, HORACE V....220 Great Northern Bldg., St. Paul, Minn.
WINTER, JOSEPH H..............................Negaunee, Mich.
WITHERBEE, F. S.........................Port Henry, New York.
WOODBRIDGE, DWIGHT E..........................Duluth, Minn.
WOODWORTH, G. L...............................Hibbing, Minn.
WORDEN, JOHN..............................Crystal Falls, Mich.

YOUNG, H. OLIN................................Ishpeming, Mich.
YOUNGS, FRANK W...............................Iron River, Mich.
YOUNGS, GEORGE C..............................Florence, Wis.
YOUNGS, G. W..................................Iron River, Mich.
YUNGBLUTH, A. J...............................Ishpeming, Mich.

## DECEASED MEMBERS.

ARMSTRONG, J. F...............................March 3rd, 1898
BENNETT, JAMES H..................................................
BULLOCK, M. C...............................January 12, 1899
BAWDEN, JOHN T....................................1899
BROOKS, T. B......................................1902

CONRO, ALBERT.......................................January 10th, 1901
DANIELS, JOHN.......................................September 13th, 1898
DICKENSON, W. E.....................................June 15th, 1899
DOWNING, W. H.......................................October, 1906
DUNSTON, THOMAS B...................................
DUNCAN, JOHN........................................June, 1904
HOLLEY, S. H........................................July 4th, 1899
HARPER, GEORGE VANCE................................March, 1905
HAYDEN, GEORGE......................................July 27th, 1902
HOUGHTON, JACOB.....................................December 30th, 1903
HINTON, FRANCIS.....................................1896
HOLLAND, JAMES......................................September 3rd, 1900
HYDE, WELCOME.......................................
JEFFERY, WALTER M...................................May 26th, 1906
JOCHIM, JOHN W......................................January 17th, 1905
LUSTFIELD, A........................................May 26th, 1904
LYON, JOHN B........................................February 13th, 1900
MARR, GEORGE A......................................March, 1905
M'VICHIE, D.........................................September 14th, 1906
OLIVER, HENRY W.....................................February 8th, 1904
PEARCE, H. A........................................1905
RYAN, EDWARD........................................1901
SHEPHARD, AMOS......................................June 6th, 1905
STANTON, JOHN.......................................February 23rd, 1906
THOMAS, HENRY.......................................December, 1905
TREVARTHEN, G. C....................................January, 1898
VAN DYKE, JOHN H....................................1906
WALLACE, JOHN.......................................1898
WILLIAMS, W. H......................................1897
WHITNEY, J. D.......................................1894

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| 3 | Mesabi and Vermilion Ranges | March 6-8, 1895, | Vol. III |
| 4 | Ishpeming, Mich | August 18-20, 1896, | Vol. IV |
| 5 | Ironwood, Mich | August 16-18, 1898, | Vol. V |
| 6 | Iron Mountain, Mich | February 6-8, 1900, | Vol. VI |
| 7 | Houghton, Mich | March 5-9, 1901, | Vol. VII |
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| 12. | Houghton, Mich | August 8-9-10, | Vol. XII |

# RULES OF THE INSTITUTE.

## I.

## OBJECTS.

The objects of the Lake Superior Mining Institute are to promote the arts and sciences connected with the economical production of the useful minerals and metals in the Lake Superior region, and the welfare of those employed in these industries, by means of meetings for social intercourse, by excursions, and by the reading and discussion of practical and professional papers, and to circulate, by means of publications among its members the information thus obtained.

## II.

## MEMBERSHIP.

Any person interested in the objects of the Institute is eligible for membership.

Honorary members not exceeding ten in number, may be admitted to all the privileges of regular members except to vote. They must be persons eminent in mining or sciences relating thereto.

## III.

## ELECTION OF MEMBERS.

Each person desirous of becoming a member shall be proposed by at least three members, approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe), upon receiving three-fourths of the votes cast. Application must be accompanied by fee and dues as provided by Section V.

Each person proposed as an honorary member shall be recommended by at least ten members, approved by the Council, and elected by ballot at a regular meeting, (or by ballot at any time conducted through the mail, as the Council may prescribe), on receiving nine-tenths of the votes cast.

## IV.

## WITHDRAWAL FROM MEMBERSHIP.

Upon the recommendation of the Council, any member may be stricken from the list and denied the privilege of membership, by the vote of three-fourths of the members present at any regular meeting, due notice having been mailed in writing by the Secretary to him.

## V.

## DUES.

The membership fee shall be five dollars and the annual dues five dollars, and applications for membership must be accompanied by a remittance of ten dollars; five dollars for such membership fee and five dollars for dues for the first year. Honorary members shall not be liable to dues. Any member not in arrears may become a life member by the payment of fifty dollars at one time, and shall not be liable thereafter to annual dues. Any member in arrears may, at the discretion of the Council, be deprived of the receipt of publications or be stricken from the list of members when in arrears six months; Provided, That he may be restored to membership by the Council on the payment of all arrears, or by re-election after an interval of three years.

## VI.

## OFFICERS.

There shall be a President, five Vice-Presidents, five Managers, a Secretary and a Treasurer, and these Officers shall constitute the Council.

## VII.

## TERM OF OFFICE.

The President, Secretary and Treasurer shall be elected for one year, and the Vice-Presidents and Managers for two years, except that at the first election two Vice-Presidents and three Managers shall be elected for only one year. No President, Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. The term of office shall continue until the adjournment of the meeting at which their successors are elected.

Vacancies in the Council, whether by death, resignation, or the failure for one year to attend the Council meetings, or to perform the duties of the office, shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; Provided, That such appointment shall not render him ineligible at the next election.

## VIII.

## DUTIES OF OFFICERS.

All the affairs of the Institute shall be managed by the Council except the selection of the place of holding regular meetings.

The duties of all Officers shall be such as usually pertain to their offices, or may be delegated to them by the Council.

The Council may in its discretion require bonds to be given by the Treasurer, and may allow the Secretary such compensation for his services as they deem proper.

At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Five members of the Council shall constitute a quorum; but the Council may appoint an executive committee, business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary and recorded by him with the minutes.

There shall be a meeting of the Council at every regular meeting of the Institute and at such other times as they determine.

IX.

ELECTION OF OFFICERS.

Any five members not in arrears, may nominate and present to the Secretary over their signatures, at least thirty days before the annual meeting, the names of such candidates as they may select for offices falling under the rules. The Council, or a committee thereof duly authorized for the purpose, may also make similar nominations. The assent of the nominees shall have been secured in all cases.

No less than two weeks prior to the annual meeting, the Secretary shall mail to all members not in arrears a list of all nominations made, and the number of officers to be voted for in the form of a letter ballot. Each member may vote either by striking from or adding to the names upon the list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing the ballot with his name, and either mailing it to the Secretary, or presenting it in person at the annual meeting.

In case nominations are not made thirty days prior to the date of the annual meeting for all the offices becoming vacant under the rules, nominations for such offices may be made at the said meeting by five members, not in arrears, and an election held by a written or printed ballot.

The ballots in either case shall be received and examined by three tellers appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected. The ballot shall be destroyed, and a list of the elected officers, certified by the tellers, shall be preserved by the Secretary.

X.

MEETINGS.

The annual meeting of the Institute shall be held at such time as may be designated by the Council. The Institute may at a regular meeting select the place for holding the next regular meeting. If no place is selected by the Institute it shall be done by the Council.

Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. No other business shall be transacted at a special meeting than that for which it was called.

Notices of all meetings shall be mailed to all members at least thirty days in advance, with a statement of the business to be transacted, papers to be read, topics for discussion and excursions proposed.

No vote shall be taken at any meeting on any question not pertaining to the business of conducting the Institute.

Every question that shall properly come before any meeting of the Institute, shall be decided, unless otherwise provided for in these rules, by the votes of a majority of the members then present.

Any member may introduce a stranger to any regular meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

## XI.

## PAPERS AND PUBLICATIONS.

Any member may read a paper at any regular meeting of the Institute, provided the same shall have been submitted to and approved by the Council, or a committee duly authorized by it for that purpose prior to such meeting. All papers shall become the property of the Institute on their acceptance, and, with the discussion thereon, shall subsequently be published for distribution. The number, form and distribution of all publications shall be under the control of the Council.

The Institute is not, as a body, responsible for the statements of facts or opinion advanced in papers or discussions at its meetings, and it is understood, that papers and discussions should not include personalities, or matters relating to politics, or purely to trade.

## XII.

## AMENDMENTS.

These rules may be amended by a two-thirds vote taken by letter ballot in the same manner as is provided for the election of officers by letter ballot; Provided, That written notice of the proposed amendment shall have been given at a previous meeting.

# COMMITTEES IN CHARGE OF ARRANGEMENTS AND ITINERARY WITH REPORT OF THE DISTRICT.

For the third time in its history the Lake Superior Mining Institute paid its visit to the copper country of Michigan. The previous visits being made in March, 1894 and March, 1901. On each visit its membership has been much increased and the attendance at this meeting was 325 members and guests.

The arrangements for the entertainment of the Institute was in charge of the local members and their friends who were interested in making the meeting a success. That they succeeded in their efforts was clearly demonstrated by the many enjoyable features connected with the trip. The following is a complete list of the several committees:

**Arrangement Committee.**

W. D. CALVERLEY, Chairman.

Graham Pope,
L. L. Hubbard,
J. F. Jackson,
C. L. Lawton.

**Transportation Committee.**

F. W. DENTON, Chairman.

W. J. Uren,
James Chynoweth,
Fred Smith,
J. L. Harris.

**Entertainment Committee.**

N. W. HAIRE, Chairman.

J. B. Cooper,
J. W. Black,
G. L. Heath,
O. P. Hood,
Geo. A. Koenig,
F. W. McNair,
R. C. Pryor,
F. L. Van Orden,
C. H. Moss,
W. A. Childs,
J. D. Ramsey,
H. W. Cake,
John Breen,
John G. Stone,
S. J. Beahan,
Robert H. Shields,
C. M. Hoar,
Lessing Karger,
Peter Ruppe, Jr.
A. D. Edwards,
F. G. Coggin,
Capt. John Jolly,
C. C. Douglass,
Z. W. Wright,
Hon. Charles Smith,
J. H. Wilson,

Samuel Rawlins,
W. M. Harris,
F. H. Haller,
Will Smith,
C. L. Noetzel,
Russell Smith,
A. D. Nicholas,
L. S. Austin,
Bert Senter,
A. L. Carnahan,
B. F. Chynoweth,
W. S. Cleaves,
James Fisher, Jr.
F. W. Nichols,
A. E. Saunders,
F. W. Sperr,
J. C. Shields,
F. J. Bawden,
Henry Brett,
W. M. Gibson,
J. B. Risque,
Frank Getchell,
C. D. Hohl,
J. T. Reeder,
Capt. Thomas Maslin,
Fred Smith,
Will Hartmann,
Capt. James Rapson,
Geo. C. Goodale,
Hon. A. T. Streeter,
R. R. Goodell,
F. McM. Stanton,
C. V. Seeber,
James R. Dee,
W. F. Miller,
J. C. Mann,
Ferd Wieber,
W. G. Rice,
Paul D. Swift,
Johnson Vivian,
A. R. Gray,
Horace J. Stevens,
A. N. Baudin,
F. I. Cairns,
Samuel Brady,
Thomas W. Armstrong,
Joseph Bosch,
James T. Fisher,
Robert W. Cowan,
Theo. J. Hennes,
W. E. Gray,
A. F. Heidekamp,
James Collie,
James Hoar,
Capt. Thomas Whittle,
Thomas E. Burgan,
W. C. Jilbert,
T. L. Chadbourne,
Dr. George W. Orr,
S. B. Harris,
Frank H. Shumaker,
C. D. Hanchette,
George H. Nichols,
John Funkey,
Michael Finn,
W. R. McMaster,
W. C. Cole,
H. L. Baer,
August Mette,
Thomas Coughlin,
William Kerredge,
Andrew Kauth,
George Ruppe,
Joseph Ruppe,
A. J. Scott,
C. A. Wright,
Jacob Baer,
W. H. Hosking,
F. S. Carlton,
W. H. Thielman,
Edward Ulseth,
Thomas M. Lyon,
Paul P. Roehm,
Joseph Hermann,
Joseph W. Selden,
H. J. Vivian,
H. S. Goodell,
R. R. Seeber,
John B. Dee,
William Condon.

## ITINERARY.

### Wednesday, August Eighth.

Train will leave Houghton at 1:45 p. m., and Hancock at 2:00 p. m., for Calumet. Afternoon to be spent at Calumet, Tamarack and Osceola locations. Supper at Calumet. Evening, a meeting of the Institute for business purposes, and reading and discussions of papers. Return to Houghton and Hancock after meeting.

### Thursday, August Ninth.

Mineral Range train will leave Houghton at 7:45 a. m.; Hancock

8:00 a. m., for a visit to the mines north of Calumet. Luncheon en route. Return to Hougthon and Hancock for supper. Evening, a meeting of the Council at the Court House at 7:00 p. m., afterwards a meeting for the annual election of officers, and any other business.

Friday, August Tenth.

Copper Range train will leave Houghton at 8:00 a. m., for a visit to the Michigan smelter, and the Copper Range mines and mills. Arrangements will be made for parties wishing to visit the smelters or mills at Lake Linden and Hubbell (which have been unavoidably omitted because of lack of time) by application to the transportation committee. The Quincy mine also may be visited easily, being but five or ten minutes ride by street car from the Portage Lake towns.

The departure of trains from Houghton on July 10th will be as follows:

The Copper Range trains leave for Ontonagon, and points south at 10:45 a. m., and 5:30 p. m.

D., S. S. & A. Ry. for Marquette at 3:35 p. m. and 10:35 p. m.

D., S. S. & A. Ry. for Negaunee and points on the Chicago & Northwestern Ry. at 3:35 p. m.; for Champion, via C., M. & St. P. Ry. at 4:50 p. m.; for Duluth at 10:15 p. m.

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Conveyances will be provided for members of the Institute who may wish to visit the Michigan College of Mines. Its Museum of Minerals and Model Room are particularly interesting. The College ranks as the foremost of its kind in the world.

The Houghton National bank extends to the members of the Institute during their visit to the Copper Country, the use of one of its offices, which will be provided with a stenographer and telephone service to all parts of the county, including the long distance service.

The northeast corner room of the Douglass House, on the main floor, has been reserved for the members' headquarters during the time of the Institute in the county.

Membes of the Institute wishing to visit the Onigaming Yacht club can procure cards of admission from Mr. Sidney Karger, chairman of the house committee, or from Mr. E. C. Taylor, secretary of the club.

The golf links will be open to members of the Institute. Mr. Graham Pope will gladly furnish admission cards and transportation.

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The program published by the committee contained a report by Mr. Horace J. Stevens on the mines in the district with some brief notes on the geology of the county and the history of the copper mining industry. This added much to the interest of the trip and as the information given is of an important nature the report is published herewith for the benefit of our members who were unable to attend the meeting. The map mentioned in this article is published elsewhere in this volume.

## MINES OF THE LAKE SUPERIOR COPPER DISTRICT.

By Horace J. Stevens, Houghton, Mich.

The map presented herewith, gives an outline of the developed portion of the Lake Superior copper district. The Keweenawan formation is very extensive, outcropping on Michipicoten Island, north of Sault Ste. Marie, on the eastward, and running through Northern Wisconsin into northeastern Minnesota on the west. Attempts at mining have been made at various points along its stretch of about 400 miles, but the developed and developing mines of the present day extend for a distance of about 100 miles only, from the Manitou mine on the northeast to the Copper Crown mine on the southwest.

The Keweenawan trap-belt is a syncline, the southern edge of which carries the developed mines. The syncline dips under Lake Superior at various angles, ranging from 22 degrees with the horizon at the Arnold mine, Keweenaw county, to 73 degrees at the Baltic mine, Houghton county. The trap-belt consists of a series of flows, perhaps nearly 200 in number, with intercalary beds of conglomerates, perhaps 20 or more in number. The amygdaloid portions of the trap-flows frequently carry native copper, though not all of them are workable. There also is much local variation from point to point, in the copper values found in these beds, locally termed amygdaloids. Many of the amygdaloids have undergone such extensive mineralogical changes as to have lost all semblance of their original character, and carry epidote, prehnite, calcite, laumonite, etc., in large quantities. The copper occurs native, in various forms, in the amygdaloids. Occasioanlly immense masses, of many tons weight, are found, while in the richer mines there is much "barrel work," *i. e.*, masses of virgin metal, ranging from a few pounds up to 100 pounds or more in weight.

The principal reliance of the mines is upon stamp-rock, that is, amygdaloid or conglomerate rock carrying native metal in sizes ranging from that of a pea down to flakes of almost microscopic dimensions, that are saved with difficulty from the slimes at the mills.

The conglomerates are of aqueous or igneous origin, and possibly of both. Where cupriferous, the conglomerates are impregnated with copper that has replaced the original cementing material, and the Calumet conglomerate, the richest bed of the district, often shows small masses of metal, up to several inches in diameter, that have completely replaced pebbles and small boulders. Copper has been found in a number of the conglomerates, but is being mined at present from two only. The Calumet conglomerate is mined by the Calumet & Hecla and also by the Tamarack, the latter working the underlay by means of vertical shafts, but the Calumet conglomerate was found unprofitable both north and south of the Calumet & Hecla lands. The Allouez, or Boston & Albany conglomerate, is worked at the Franklin Junior mine.

In addition to the bedded deposits there are fissure veins, usually crossing the strata at approximately right angles, with an approach to vertical dip. The fissures were much worked in early days and gave several mines that paid millions of dollars each in profits. At present there are no active mines of this class, the last to close down having been the Phœnix, in Keweenaw county, which suspended in June, 1905.

With the development of the industry and the increase in depth attained, the importance of masses has decreased, and at present the main reliance of all mines working the amygdaloid and conglomerate strata is upon stamp-rock. The heavy copper is found, as a rule, in the upper workings of the mines, though continuing downward for perhaps 3,000 feet in the richer mines. Below a depth of 4,000 feet a decrease in metallic values is noted in every mine that has exceeded that depth.

None of the mines opened on fissure veins ever reached a depth of 3,000 feet, the copper values in the stratified beds proving the more persistent at depth. The deepest shaft of the district, and of the world, is No. 3 Tamarack, a vertical shaft bottomed at a depth of 5,139 feet from the surface. In addition to the native copper deposits, there are occasional fissure-veins, carrying copper ores, but none of these have proven of permanent value, the mineralization being confined, as a rule,to a comparatively short distance each side of the crossing of a copper-bearing stratified bed. In addition to the more common copper ores, such as chalcopyrite, bornite and chalcocite, several arsenical ores peculiar to the district have been identified, among these being the interesting compound arsenides of copper and nickel, known as mohawkite and keweenawite, found in a fissure-vein at the Mohawk mine in Keweenaw county.

Owing to the peculiar geological and mineralogical conditions of the district, a single mining company may open several entirely distinct mines on a single tract. Among such cases is that of the Calumet & Hecla, which, in addition to its main mine on the Calumet conglomerate, has a parallel mine, 730 feet eastward, opened on the Osceola amgygdaloid, while a third parallel mine is being opened on the Kearsarge amygdaloid, 2,200 feet east of the Osceola bed. The Tamarack also works the Osceola amygdaloid as well as the Calumet conglomerate, opening both beds by vertical shafts, so that it may be said that separate mines are opened and worked by the same company, either tandem or side by side. The Centennial mine made a failure of the northern extension of the Calumet conglomerate, then moved eastward on its own lands and opened a second mine on the Osceola amygdaloid, which, not promising well, was closed, and a third mine was opened on the Kearsarge amygdaloid. The Allouez company also is opening its third parallel mine and in both the cases the third mine is the best of the three.

The following description gives brief detailed references to the principal active mines of the Lake Superior copper district, located in the three counties of Houghton, Keweenaw and Ontonagon.

*Adventure*—The Adventure mine is at Greenland, Ontonagon county. Samuel Brady, superintendent; Allan Eddyvean, mill superintendent. Company was organized in 1898 and consolidated the old Adventure, Hilton and Knowlton mines. Former was opened in 1850, along a line of old pits dug by prehistoric miners. Property is still in the development stage, though stamping a small quantity of rock, and though nearly dead two years ago, now looks very well. Made 1,606,208 pounds fine copper in 1905.

*Ahmeek*—The Ahmeek mine is at Kearsarge, Keweenaw county. Norman W. Haire, general manager; Wm. J. Uren, general superintendent. The company is an old one, recently grown active through the development of adjoining lands proving the continuance of the rich Kearsarge lode under the Ahmeek tract. The property is of exceptional promise, and interesting because it shows a big Lake Superior copper mine in an early stage of development. Made 1,552,957 pounds fine copper in 1905.

*Allouez*—The Allouez mine is at Allouez, Keweenaw county. James Chynoweth, superintendent. The company is an old one, with a new mine. The old Allouez mine, opened on the Allouez conglomerate, was never profitable to the owners, and a second mine, opened on the Osceola lode, did not promise well. As the Allouez owns the underlay, but not the outcrop of the Kearsarge amygdaloid, the shaft is sunk to the lode at an angle of 80 degrees, but on reaching the copper bearing stratum is deflected to the angle of the bed. Backguides are used for the cages, which have eight wheels each. The Allouez is universally conceded by local mining men to be a property of unusual promise. Is producing by a leased group at the Centennial mill.

*Atlantic*—At Atlantic mine, Houghton county. Frank McM. Stanton, agent; Theo. Dengler, superintendent; F. G. Coggin, mill superintendent; A. D. Edwards, clerk; John

Stratton, mining captain. Employs about 700 men normally. Has paid dividends of $940,000 and made 4,049,731 pounds fine copper in 1905. Has a very complete mining plant, including some powerful hoists, and is more frequently quoted than any other property in the United States or abroad as an example of an exceedingly low-grade mine, economically and successfully worked, the copper secured from the rock averaging only from 11 to 16 pounds per ton—0.55 to 0.80 per cent of copper. The metal is distributed with exceptional uniformity throughout the rock, but is very fine and requires great care in milling. The mill, at Redridge, on the shore of Lake Superior, has six stamps. The Atlantic and Baltic make joint use of a steel gravity dam across the Salmon Trout river, which impounds about 1,250,000,000 gallons of water. This dam, in five steel sections, anchored by its own weight in a concrete base, is the first and, so far as known, the only structure of its kind. The mine has suffered during 1906, from subsedence of the overlying strata, causing what is locally termed "air blasts," which are artificial earthquakes of small size.

*Baltic*—At Baltic, six miles south of Houghton. F. W. Denton, superintendent; F. G. Coggin, mill superintendent; William C. Cole, clerk; Martin Trethewey, mining captain. This property, controlled by the Copper Range Consolidated Co., is one of the newer mines of the district, and has not yet obtained its full growth. It was the pioneer mine on the Baltic lode, the easternmost or oldest of the amygdaloid beds mined in the district. The lode is very wide, and an interesting and successful system of dry-walling with waste rock is employed underground. It has a good mining equipment, but not as heavy machinery as is found at the older and deeper mines. The stamp mill is at Redridge, on Lake Superior, opposite that of the Atlantic. Made 14,384,684 pounds fine copper in 1905.

*Calumet & Hecla*—At Calumet. This mine was opened in a wilderness, and has seen a mining camp of 40,000 souls spring up about its shafts. James MacNaughton, superintendent; Will A. Childs and W. M. Gibson, assistant superintendents; W. H. Cake, mill superintendent; James B. Cooper, smelter superintendent; J. H. Lathrop, chief clerk; Fred S. Eaton, cashier; E. C. Grierson, chief engineer; Chas. Smith, smelter clerk; James Milligan, chief mining captain. The mine was opened in 1866 and paid dividends of $92,350,000 to the end of 1905. No other mining corporation in the world has paid an equal amount in profits. The largest payments were in 1899, when dividends were $10,000,000. It produced 80,341,029 pounds fine copper in 1904, being third among the world's producers in that year and made 95,100,610 pounds fine copper in 1905, taking first rank once more among the copper producers of the globe. A book several times the size of the present paper, would be required to give anything like a complete condensed description of this property and an entertaining volume of several hundred pages might be written without exhausting the subject. Merely a few salient features can be touched upon in this brief description.

The Calumet & Hecla mine proper is opened on the Calumet conglomerate bed for a distance of upwards of two miles along the outcrop. There are 12 shafts on the dip of the lode, 37 degrees 30 minutes, and one vertical shaft to the westward, this latter cutting the conglomerate at depth of 3,287 feet, and being bottomed at a depth of 4,920 feet. The deepest incline shaft, No. 4 Calumet, has a depth of 8,100 feet on the dip of the lode. The conglomerate mine is divided into four sections, known as the Calumet, Hecla, South Hecla (or Black Hills) and Red Jacket. Outcropping at an average distance of 730 feet to the eastward is the Osceola amygdaloid, on which are five shafts. Nos. 13 to 17 inclusive, while about one-half mile east of the conglomerate three new shafts, Nos. 19, 20 and 21, are being sunk on the Kearsarge amygdaloid bed. An interesting feature is a blind shaft, now being sunk to develop the "five forties," a tract of 200 acres lying between the Tamarack and the Tamarack Junior mines, and inaccessible by any of the present shafts. This blind shaft starts from the drifts at the bottom of No. 4 Calumet shaft, which has a vertical depth of 4,748 feet and an actual depth of 8,100 feet on the dip of the lode. To sink a new shaft below the bottom of an old shaft, itself more than a mile and a half in depth, is a novelty in mining practice. The Calumet conglomerate varies from 8 to 40 feet in width, averaging 12 feet in cross-section, giving about 43,200 tons of stamp-rock per acre; or, deducting ground left in pillars, which are 75 feet on either side of each shaft, there is enough rock under every average acre of surface to run the mill less than one week. The ground is treacherous and requires heavy timbering and constant watchfulness, taking about 30,000,000 feet of timber annually for underground shoring. The mine has suffered serious losses from fire on five different occasions, and great vigilance is exercised to detect any incipient underground blaze. To fight mine fires there are watchmen, pipe-lines and hydrants, with fire-hose, chemical extinguishers, fire-alarm systems, underground telephones and a system of fire-doors by which the mine can be divided into sections.

The machinery equipment of the mine is bewildering in its immensity. At No. 4 Calumet shaft is the 4,700-h.p. engine Superior and the 7,000-h.p. engine Mackinac, the latter operating a 500-drill air-compressor. There also are auxiliary engines of 2,000 and 600-h.p., and several smaller engines. of 600, 900 and 2,000-h.p., and a 144-drill air-compressor. The G. H. & S. engine house has two engines of 2,000-h.p. each, and the engine house for Hecla shafts Nos. 7 and 8 has two 2,000-h.p. engines, operating 25-foot drums by spur-gearing and a 5,000-h.p. Leavitt engine operating the man-cars. The Red Jacket shaft has an 8,000-h.p. quadruple hoist and a boiler house with ten 1,000-h.p. boilers. There are many smaller engine houses, all with powerful machinery. At the Red Jacket shaft the Kimberley system of skips swung under cages is in use, greatly increasing the hoisting capacity.

The company owns about 1,200 dwelling houses, and about 1,000 houses have been built by employes on the com-

TAMARACK NO. 5 SHAFT.

(Photo by Nara, Calumet.)

MOHAWK MINE.

Showing Three Shaft Rock Houses and Two Power Plants.

(Photo by Nara, Calumet.)

CALUMET & HECLA'S "SUPERIOR" ENGINE.
Showing Lower Deck Only.
(Photo by Nara, Calumet.)

CALUMET & HECLA MINE.
Showing Seven Shaft Rock Houses and Gratiot Power Plant.
(Photo by Nara, Calumet.)

COPPER RANGE CONSOLIDATED—Development at the Globe.

CALUMET & HECLA—Stamp Mills and Electrical Generating Station.

CALUMET & HECLA—RED JACKET SHAFT.
(Photo by Nara, Calumet.)

CALUMET & HECLA—"SUPERIOR" POWER PLANT.
(Photo by Nara, Calumet.)

pany's lands. Several complete fire departments are maintained at various points. About 30 churches and a half dozen school houses have been built on the company's land and club houses and an aid fund are maintained for employes. The Calumet & Hecla company owns a fleet of steel steamers and a private ship canal, deep enough to float any vessel on the Great Lakes. Sawmills are owned and operated at various points, and a big auxiliary smelter, including an electrolytic plant with 700 tanks, is maintained at Buffalo.

The stamp mills are at Lake Linden, four miles from the mine, and connected therewith by a private railroad. The mills are in two sections, with 11 stamps each, the southernmost, or Calumet mill, having an addition of six stamps, giving a total of 28 stamps in both mills. The mills are being rebuilt of steel, in two sections each, about one year being required for reconstructing each section. The present milling capacity of 7,000 tons per day will be increased to nearly 10,000 tons, when the remodeling is completed, giving the Calmuet & Hecla a crushing capacity greater than the combined capacity of Homestake, Treadwell and Simmer & Jack, the three gold mines of the world having the largest mills. Interesting features at the mills are the pumps and sand-wheels. The pumping engine Michigan, of 60,000,000 gallons daily capacity, is the largest in the world. The sand-wheels, used to elevate the sludge, are all giants, the largest being the new 64-foot wheel in the Hecla wheelhouse. This wheel weighs 500 tons and is driven by a 700-h.p. dynamo. The smelting plant is at Hubbell, a mile south of the mills at Lake Linden.

*Centennial*—Just north of Calumet. James Chynoweth, superintendent; John Pentecost, mining captain. This mine is an old mine remodeled. The original Centennial was opened on the northern extension of the Calumet conglomerate, which proved unprofitable. A second mine on the Osceola amygdaloid was but little better, hence a third mine has been opened on the Kearsarge amygdaloid. The square mile owned by the Centennial company carried the underlay, but not the outcrop of the Kearsarge bed, hence a few acres carrying the outcrop were bought of another owner, and a 90-foot right-of-way secured to connect the new tract with the old on the south-east corner. Two shafts were sunk, and in order to develop the entire square mile of underlay, it was necessary to divert the northernmost shaft about 15 degrees northward, upon the plane of the lode, after entering the main tract. Some delicate and novel engineering features were presented for solution in this work. The Centennial stamp mill, at Grosse Pointe, Portage lake, was built by the Arcadian company, which was the Standard Oil company's first introduction to copper, and cost somebody about $3,000,000. The mill went into commission on Centennial rock in July, 1904, and the mine made 1,446,584 pounds fine copper in 1905.

*Champion*—At Painesdale, 10 miles south of Houghton. F. W. Denton, general manager; F. G. Coggin, mill superintendent; John Broan, mining captain; M. J. Harrington, clerk. Mine is a new property, opened in 1899, opened on the Baltic lode, which is both wide and rich, and the property is of great merit, with the brightest prospects. Made 15,707,426 pounds fine copper in 1905.

*Copper Range*—The Copper Range Consolidated Co. is not directly a producer of copper, being a securities-holding corporation, owning the stock of the Baltic and Trimountain mines and a half-interest in the Champion mine, also the Copper Range railroad, part of the Michigan smelter and extensive tracts of mineral lands on the South Range. The construction of the Copper Range railroad (R. T. McKeever, general manager) has made possible the development of the great mineral territory lying between Portage lake and the Ontonagon river, and the company has been the most important factor in the opening of new mines in the Lake Superior copper district.

*Copper Crown*—This is the westernmost active mine of the Lake Superior copper district, being located about eight miles north of Matchwood. The property is owned by a St. Louis company, which made many foolish mistakes in its earlier work, but which has settled down to more conservative operations along the lines approved by the collective experience of 60 years gained by the practical mining men of the Lake Superior copper district. The showing on the Norwich property is considered encouraging. Capt. J. F. Finnegan, superintendent.

*Franklin and Franklin Junior*—Both the Franklin and the Franklin Junior mines are owned by the Franklin Mining Co. Richard M. Edwards, superintendent; Edward Warne, mill superintendent; Arno Jaehnig, clerk; Cyrus Truan and John Doney, mining captains.

The old Franklin is at Hancock, next north of the Quincy, and is merely a scram, its side-lines cutting off the lode, still payable, at a depth of 3,200 feet. The Franklin Junior, three miles north, originally was the Albany & Boston, and later the Peninsula. The Junior is working a wide, hard, lowgrade conglomerate, but is securing a large production, the property being managed with great prudence and zeal. The mill is at Grosse Pointe, adjoining that of the Centennial. Made 4,206,085 pounds fine copper in 1905.

*Isle Royale*—At Houghton. Norman W. Haire, general manager; Wm. J. Uren, general superintendent; Jas. E. Richards, mine superintendent; James G. Glanville, mill superintendent; H. D. Haddock, clerk. The Isle Royale affords a striking example of both the uncertainties and possibilities of Lake Superior copper mining. The company was organized in 1897 and took over three old mines on the hill south of Houghton. Later, another new company with large landed area and capital was absorbed, giving the Isle Royale $2,000,000 in cash for development and equipment, after the lands were paid for. Of this amount the sum of $1,500,000 was used in opening a large new mine below the level of the old workings, and in building a modern mill. The equipment is of the best, the eastern management is experienced and successful, and the local management is good, but the mine has proven a disappointment. One of the two new shafts was burned

December, 1903, and prospects for the mine were blue, but the management did not haul down the flag, preferring to make systematic exploration of its lands in search of something better. A diamond drill gave a rich core from the Isle Royale lode about two miles south of the mine workings, and a shaft, begun in 1904, is showing good ground, while explorations are now underway on the northern extension of the Baltic lode. Made 2,973,761 pounds fine copper in 1905.

*Keweenaw*—The Keweenaw Copper Co. holds extensive tracts of mineral land in Keweenaw county and is building the Keweenaw Central railroad to open the mineral territory north of Calumet. The road is to be completed this year, after which mining operations will be conducted more actively, being confined at present to diamond drilling and making ready for an active mining campaign, beginning in 1907. The company also plans the development of a considerable water power on the Montreal river, using Mosquito lake for a storage dam. Chas. A. Wright, president and general manager; Capt. Thos. Hoatson, mining director; John C. Shields, railway superintendent.

*Manitou*—The mine, formerly known as the Delaware, on which about $3,300,000 was sunk by numerous preceding owners is now owned by the Calumet & Hecla Mining Co., which with "genuine Calumet & Hecla luck" (some people might call it good sound sense, rather than luck) is developing a promising mine on the Montreal river amygdaloid.

*Mass*—At Mass City, Ontonagon county. James M. Wilcox, superintendent; Thomas Hall, mining captain; Fenner Douglass, engineer. This company is a consolidation of three early-day mines and two old prospects. The mill is at Keweenaw bay. The Mass has six parallel cupriferous beds, opened by adits and crosscuts at various levels. Made 2,007,950 pounds fine copper in 1905.

*Michigan*—At Rockland, Ontonagon county. Samuel Brady, superintendent; S. H. Brady, assistant superintendent; J. E. Vanse, engineer. Began production with one leased stamp at the Mass mill, late in 1903. The mine is interesting by reason of presenting geological peculiarities found nowhere else in the district. The property includes the old Minnesota mine, opened on a conglomerate contact vein, which paid dividends of $1,820,000. Only 140 feet north of the Minnesota vein is the Calico amygdaloid, on which three shafts have been sunk by the Michigan. Running from the Calico at surface, into the Minnesota at depth, is the North Minnesota fissure-vein, while another branch vein, taking a similar course, is found at depth. There also are foot wall and hanging wall veins. The old Minnesota mine was unwatered by drill holes bored from each successive level of the Calico shafts, as they were sunk. Made 2,891,796 pounds fine copper in 1905.

*Michigan Smelter*—The Michigan smelting works, two miles west of Houghton, on Portage lake, is a new plant, owned by the Baltic, Trimountain, Champion, Atlantic, Wolverine and other mines of the Stanton and Paine groups. It has an annual capacity of about 60,000,000 pounds of refined copper, and is the most modern metallurgical plant of the district, embodying a number of labor-saving devices and other improved features not employed heretofore in the district. The plant was designed by Frank Klepetko, the designer of the 10,000-ton Washoe plant at Anaconda, Mont., which is by far the largest in the world, and is under the superintendence of Frederick I. Cairns.

*Mohawk*—At Kearsarge, Keweenaw county. The mine is the northernmost yet opened on the Kearsarge lode and is under the same management as the Wolverine. Fred Smith, superintendent; Willard J. Smith, assistant superintendent; Barney S. Shearer, mill superintendent; F. William Hartmann, engineer; Frank Getchell, clerk. Is a fine new mine which became a dividend payer in 1905. The mine is interesting because of a fissure-vein crossing the Kearsarge bed at right-angles, carrying mohawkite and keweenawite along the intersection of the stratified bed and fissure. The stamp mill is at the mouth of Tobacco river, on Traverse bay, Lake Superior. Made 9,387,614 pounds fine copper in 1905.

*Osceola Consolidated*—At Osceola, just south of Calumet. Norman W. Haire, general manager; William J. Uren, general superintendent; A. Lincoln Burgan, mill superintendent. Property consists of four separate mines, of which the Tamarack Junior, opened on the underlay of the Calumet conglomerate, is idle. The Osceola mine proper is next south of the Calumet & Hecla, and was first opened on the conglomerate, only a few acres of which proved payable. The North and South Kearsarge mines, opened on the Kearsarge amygdaloid, are large principal producers and are properties of great merit. The Osceola paid dividends of $4,824,200 to the end of 1905. The mills on Torch lake are very extensive and the Osceola now ranks in tonnage stamped and copper made second only to the Calumet & Hecla. A 40,000,000-gallon pump, operated jointly for the Osceola and Tamarack mills, is an interesting feature. Made 18,938,965 pounds fine copper in 1905.

*Quincy*—At Hancock. Is known locally as "the Old Reliable." Chas. L. Lawton, superintendent; James W. Shields, mill superintendent; Thomas Whittle, mining captain; Charles K. Hitchcock, engineer; Will P. Smith, smelter superintendent; William Bath, smelter clerk. Employs about 1,700 men. The mine was opened in 1848 and became a dividend-payer in 1862, and has paid, to the end of 1905, 74 dividends, aggregating $15,220,000, ranking in profits disbursed second only to the Calumet & Hecla. It has a magnificent surface equipment, including an 8,000-h.p. hoist, extensive shops, railroad, etc. The mine is very deep, being only a trifle less than a mile on the dip of the lode, which is much sharper than at Calumet, to the northward. Some idea of the great depth of the mine may be gained by looking north from Houghton, at the hill crowned by No. 7 shaft house, and reflecting that four-fifths of the depth of the mine is below the waters of Portage lake, while but one-fifth is above. Another way of appreciating the depth is found by reflecting that the deep levels of the mine pass entirely under the old Franklin mine. The stamp mills, at Mason, on Torch lake, are crushing about 3,700 tons of rock daily. Electric haulage is used extensively in the mine. The smelter is in Ripley, at the foot of the hill below the mine, on the Hancock side of Portage lake. Made 18,827,557 pounds fine copper in 1905.

*Superior*—Two miles south of Houghton. Is a local company, in which considerable stock has been bought by the Calumet & Hecla, and that company has an option, expiring Dec. 31, 1906, on enough additional stock to give a control, with 51 per cent. of the issued shares. The mine is being opened on the northern extension of the Baltic amygdaloid and has one shaft, now opening the fourth level, while a second shaft was started nearly one-half mile southwest in June, 1906. James MacNaughton, general manager; Joseph Biscombe, mining captain.

*Tamarack*—At Calumet. Norman W. Haire, general manager; Wm. J. Uren, general superintendent; A. Lincoln Burgan, mill superintendent; C. D. Hohl, engineer; John T. Reeder, clerk. This mine is famous as the deepest in the world. It has five shafts, all vertical, working the underlay of the Calumet conglomerate and part of the underlay of the Osceola amygdaloid. It has paid dividends of $8,700,000 to the close of 1905, and produced 14,961,885 pounds fine copper in 1904. No. 1 Tamarack shaft, when first planned to sink vertically for nearly one-half mile on the chance of cutting the conglomerate, was regarded by many as the dream of a madman, but proved an entire success. No. 3 shaft, vertical, is the deepest in the world, being bottomed at 5,139 feet. No 5 shaft also vertical, and the second deepest in the world, was started in August, 1895, and at that time the late Captain William E. Parnall stated that the shaft would be bottomed in the lode, at a depth of about 4,650 feet, about January 1, 1902. The shaft actually cut the conglomerate on December 20, 1901, at a depth of 4,662 feet, being but 12 feet deeper and bottomed 11 days earlier than was predicted, when the first sod was cut, more than five years before.

The machinery equipment at all five vertical shafts is very heavy, being the most powerful at shafts Nos. 3 and 5. At No. 5 there are two 6,500-h.p. double drum hoists, and a 100-drill air-compressor. No. 5 shaft is of interest because of its framing and other features, in addition to its stupendous depth of 5,086 feet. At No. 5, the combination shaft house and rock house, built of steel, on separate foundations yet forming one building, will repay study. The hoisting plant at No. 3 shaft also is worthy of inspection. The Tamarack has two stamp mills on Torch lake, near those of the Osceola, equipped with modern crushing and washing machinery, with steeple-compound stamps, the latest development in milling practice in this district.

*Tamarack-Osceola Copper Manufacturing Co.*—At Dollar Bay, four miles east of Hancock. The plant includes a smelter, handling the mineral of the Osceola, Tamarack and Isle Royale mines, a manufacturing plant, making sheets and wires, the latter being the only copper rolling and drawing mill in the northwest.

*Trimountain*—At Trimountain, eight miles south of Houghton and midway between the Baltic nad Champion mines. F. W. Denton, superintendent; Edward Koepel, mill superintendent; H. T. Mercer, engineer; Benjamin D. Noetzel, clerk. This is a new mine, opened on the great Baltic lode, presenting many of the same features as are found at the Baltic and Champion mines, with which it is closely affiliated. The surface plant is extensive and the property is managed with much vigor and success. The stamp mill is at Beacon Hill, two miles west of Redridge, on Lake Superior, with four stamps and a 20,000,000-gallon pump taking wash water from a well connected with Lake Superior by a 40-inch riveted-steel pipe running to a crib in the lake 1,400 feet from the shore. Made 10,476,462 pounds fine copper in 1905.

*Victoria*—At Victoria, Ontonagon county. This mine is the westernmost of the active mines of the Lake Superior copper district. George Hooper, superintendent. Extensive underground development has been secured, and the property has just gotten onto a productive basis. The large natural water power at Glenn Falls, on the west branch of the Ontonagon river, a short distance from the mine, has been improved, and several thousand horsepower are delivered by means of a canal diverting the water from the river to a 20 by 20-foot shaft 300 feet in depth. Instead of using penstocks and turbines, the water is made to compress the air at the bottom of the shaft, affording a novel hydraulic air-compression plant. The topography at the Victoria is much bolder than in Houghton county, and the scenery about the Ontonagon county mines is unusually striking.

*Winona*—At Winona, Houghton county, 25 miles southwest of Houghton. Frank McM. Stanton, superintendent; J. O. Peterson, mining captain; William Van Orden, clerk. This mine produced 646,025 pounds fine copper in 1904, though still in the development stage, but was not a producer in 1905. It has a fair plant of mining machinery, suited to the present requirements.

*Wolverine*—At Kearsarge, Houghton county. Fred Smith, superintendent; Willard J. Smith, assistant superintendent; B. S. Shearer, mill superintendent; F. William Hartmann, engineer; William Pollard, mining captain. This small, but very rich property, is most excellently handled, securing from 29 to 31 pounds of refined copper per ton of rock stamped, which is the largest average return from any amygdaloid mine of the district, and second only to the Calumet & Hecla. Its stock sold at $2.25 per share 10 years ago, and the mine now pays semi-annually dividends of $8 per share. The stamp mill at the mouth of the Tobacco river, on Traverse bay, Lake Superior, is a duplicate of the mill of the Mohawk mine. Made 9,464,418 pounds fine copper in 1905 and has paid dividends of $2,430,000 to the end of 1905.

# STATISTICS OF LAKE SUPERIOR COPPER MINES.

(Compiled by Horace J. Stevens.)

| Name of Mine. | Location. | Superintendent. | Production Lbs. 1901 | Production Lbs. 1905. | Assessme'ts To Jan. 1, 06 | Dividends to Jan 1, 1906. |
|---|---|---|---|---|---|---|
| Adventure | Greenland, Ontonagon county | Samuel Brady | 29,361 | 1,606,208 | $ 1,850,000 | $.......... |
| Ahmeek | Kearsarge, Keweenaw county | Wm. J. Uren | .......... | 1,552,957 | 875,000 | .......... |
| Allouez | Kearsarge, Keweenaw county | James Chynoweth | .......... | .......... | 2,225,000 | .......... |
| Atlantic | Atlantic, Houghton county | Frank McM. Stanton | 4,666,880 | 4,049,731 | 980,000 | 990,000 |
| Baltic | Baltic, Houghton county | F. W. Denton | 2,641,432 | 14,384,684 | 1,800,000 | 1,250,000 |
| Calumet & Hecla | Calumet, Houghton county | James MacNaughton | 82,519,676 | 95,100,610 | 1,200,000 | 92,350,000 |
| Centennial | Calumet, Houghton county | James Chynoweth | 806,400 | 1,446,584 | 1,870,000 | .......... |
| Champion | Painesdale, Houghton county | F. W. Denton | .......... | 15,707,426 | 2,500,000 | 1,500,000 |
| Elm River | Elm River, Houghton county | James Chynoweth | .......... | .......... | 1,200,000 | .......... |
| Franklin | Hancock, Houghton county | R. M. Edwards | 3,757,419 | 4,206,085 | 220,000 | 1,240,000 |
| Isle Royale | Houghton, Houghton county | Wm. J. Uren | 2,171,955 | 2,973,761 | 2,000,000 | .......... |
| Mass | Mass City, Ontonagon county | Jas. M. Wilcox | 837,297 | 2,007,950 | 1,900,000 | .......... |
| Mayflower | Calumet, Houghton county | James Chynoweth | .......... | .......... | 800,000 | .......... |
| Michigan | Rockland, Ontonagon county | Samuel Brady | .......... | 2,891,796 | 1,600,000 | .......... |
| Mohawk | Kearsarge, Keweenaw county | Fred Smith | 160,897 | 9,387,614 | 2,100,000 | .......... |
| Old Colony | Calumet, Houghton county | James Chynoweth | .......... | .......... | 1,100,000 | .......... |
| Osceola | Calumet, Houghton county | Wm. J. Uren | 13,723,487 | 18,938,965 | 1,700,000 | 4,824,200 |
| Phoenix | Phoenix, Keweenaw county | Frank McM. Stanton | 93,643 | 273,219 | 1,200,000 | .......... |
| Quincy | Hancock, Houghton county | Chas. L. Lawton | 20,540,720 | 18,827,557 | 200,000 | 15,570,000 |
| Rhode Island | Calumet, Houghton county | M. M. Dennis | .......... | .......... | 900,000 | .......... |
| Tamarack | Calumet, Houghton county | Wm. J. Uren | 18,000,852 | 15,824,008 | 320,000 | 8,700,000 |
| Tecumseh | Calumet, Houghton county | R. M. Edwards | .......... | .......... | 500,000 | .......... |
| Trimountain | Trimountain, Houghton county | F. W. Denton | .......... | 10,476,462 | 1,900,000 | 300,000 |
| Victoria | Victoria, Ontonagon county | George Hooper | .......... | .......... | 1,100,000 | .......... |
| Winona | Winona, Houghton county | F. W. Denton | .......... | .......... | 1,100,000 | .......... |
| Wolverine | Kearsarge, Keweenaw county | Fred Smith | 4,946,126 | 9,464,418 | 230,000 | 1,770,000 |
| Wyandot | Wyandot, Houghton county | F. L. VanOrden | .......... | .......... | 800,000 | .......... |
| Miscellaneous | .......... | .......... | 658,000 | 50,000 | 21,297,700 | 8,008,620 |
| Totals | .......... | .......... | 155,604,145 | 229,170,035 | $55,467,700 | $136,662,820 |

## DESCRIPTION OF THE INSTITUTE TRIP TO THE DIFFERENT MINES, MILLS AND SMELTERS.

For the full and detailed report on the different interests visited by the members on the occasion of this meeting, as well as information about properties not included in the itinerary, the secretary is indebted to Mr. Arthur L. Carnahan. His close association with the copper mines has enabled him to keep in touch with the new developments in the district and the progress attained during the five years, since the last visit of the Institute:

The session of the Lake Superior Mining Institute in the copper country at its twelfth annual meeting, possessed unique interest, in that it offered an opportunity for comparisons that were unusual. Five years previously it had held its session in the same district at a time when a great copper boom was on the wane. At that time its members saw—or had the opportunity to see—a large number of new properties just at the beginning of their careers, the outgrowth of the lively interest which for three years preceding had been taken in copper mining promotions and developments. Upon the occasion of this session opportunity was again afforded to see these properties, after a growth of five years.

The results of the mining promotions of 1898-99 in the copper country were most gratifying, and the successful mines that were developed during the five years of growth in the interval between the two visits of the Institute were surprising to those who had not kept themselves familiar with progress there in that time.

Going over the list, one finds that there were 25 mining properties on Keweenaw peninsula, either newly organized or revived from a moribund or inactive state by the interest attracted to copper mining at the close of the last century. These were the Adventure, Arcadian, Arnold, Ashbed, Baltic, Centennial, Champion, Elm River, Franklin Junior, Humboldt, Isle Royale, Mass, Mayflower, Meadow, Mesnard, Mohawk, Michigan, Old Colony, Phoenix, South Kearsarge, Rhode Island, Trimountain, Victoria, Winona and Wyandot. Practically all of these were at work at the time of the Institute's visit in 1901. With the opportunity for a five-year try-out, they were all active at the time of the visit in 1906 except five, the inactive ones being the Arnold, Humboldt, Meadow, Mayflower and Phoenix. Of the 20 active ones remaining, all were producers except six, those still remaining in the prospective stage being the Arcadian, Ashbed, Elm River, Old Colony, Rhode Island and Wyandot. Of the 14 producers on the list, six have attained positions that are "eminently respectable," as they are in the dividend class or are profitable factors of dividend paying companies. These are the Baltic, Champion, Mesnard, Mohawk, South Kearsarge and Trimountain. The remaining eight shippers may be divided into two classes—those whose developments promise reasonable success, which are the Centennial, Franklin Junior, Isle Royale, Mass, Michigan and Winona, and those whose ability to become self-supporting is not yet fully demonstrated, which are the Adventure and Victoria.

A recapitulation, then, shows that of the 25 companies which were in their infancy five years ago, five have discontinued, six of the remaining active ones have not discovered pay ground, two are shipping but have not fully assured their future, six are shipping from lodes that promise permanency and six are returning earnings to their owners.

In addition to this, two new mines have been developed to a position of profitable operations in less than the five-year interval, as they inaugurated their work after the former visit of the Institute. These are the Ahmeek and Allouez. Both have developed exceptionally rich ground and have an unquestioned future assured. Four others of still more recent inception have very fair prospects, with good lodes but still lacking in adequate development. These are the Keweenaw, Hancock, Superior and Lake. And finally the Calumet & Hecla has opened nine new permanent shafts, revived five idle ones and is exploring another property with a view to resuscitating it. The new shafts include two on the Montreal lode at its Delaware property, two on the Kearsarge lode at its Gratiot property, three on the Kearsarge lode on its main tract at Calumet and two on the Kearsarge lode at its Caldwell property. The five shafts in which activity has been renewed are on the Osceola lode on its main tract at Calumet. The property undergoing exploration is the Nonesuch, in the Porcupine mountains.

This enumeration of development shows that the new growth of the copper country possesses an unquestioned permanency, and the success that has attended the undertakings is a tribute to the ability of the financial and engineering genius by which they were directed. The meaning of this development as a source of copper production is best given in figures. Following is a table which shows roughly the total output of the producers already enumerated whose inception and growth belong to the last eight years:

| | Pounds. |
|---|---|
| Adventure | 6,000,000 |
| Ahmeek | 4,000,000 |
| Allouez | 3,000,000 |
| Arcadian | 3,000,000 |
| Baltic | 49,000,000 |
| Calumet & Hecla (Osceola lode) | 10,000,000 |
| Centennial | 3,000,000 |
| Champion | 43,000,000 |
| Franklin Junior | 25,000,000 |
| Isle Royale | 15,000,000 |
| Mass | 12,000,000 |
| Mesnard | 2,000,000 |
| Michigan | 6,000,000 |
| Mohawk | 24,000,000 |
| Phoenix | 2,000,000 |
| South Kearsarge | 30,000,000 |
| Trimountain | 36,000,000 |
| Victoria | 500,000 |
| Winona | 2,000,000 |
| | 225,000,000 |

This approximation does not pretend to be exact—some of the figures may be 1,000,000 pounds too high or too low. In fact several of the mines enumerated will average an output of nearly 1,000,000 pounds each per month, so that a few months more or less in the time fixed for terminating the estimate would make considerable difference in the result. The object of the table is to present a picture representing the magnitude of the copper mining development that had its start in the new work inaugurated during the last eight years. The copper production from that source alone—225,000,000 pounds—since the work began is approximately the equivalent of a year's output from the entire district. At the average price that has prevailed during the period it has brought the companies at least $35,000,000. That is surely a fair reward for the assessments paid in on these same companies, which aggregate less than $20,000,000. The best of these properties are yet in their infancy and several of them give promise of rivaling the success already attained by the dividend payers in the group.

## FIRST DAY'S ITINERARY.

The Institute established its headquarters for the session of 1906 at the Douglass House in Houghton. Members began to assemble on Tuesday, August 7th, and when the official session began on the morning of Wednesday, August 8th, a very large proportion of the membership was present. The Chicago, Milwaukee & St. Paul and Chicago & Northwestern trains arriving at noon over the Duluth, South Shore & Atlantic tracks brought practically all of the remaining members who attended the session.

During Wednesday forenoon large crowds visited the Michigan College of Mines, automobile service for that purpose being provided by the local committees. At the college the members of the faculty and of the staff of instruction entertained the visitors and showed them through the institution. The growth of the college was a gratifying surprise to those who had not visited it recently. It now has separate buildings for seven of its departments. These include Hubbell hall, where the mineralogical laboratories, physics laboratories, library, executive quarters, and many recitation rooms are situated, the Assay building, the Chemical building, the Mechanical Engineering building, the Metallurgical building, the Mining building and the Stamp Mill. The college is also being equipped with a magnificent gymnasium, the funds for which are provided by the alumni, student body and friends of the institution, who contribute through private subscription. The building is finished and the interior is well advanced toward completion.

It was shortly after 2 o'clock when the special train over the Mineral Range railroad left the Houghton depot for Calumet, to carry the Institute on its first trip to the mines. At Hancock the train received several additional passengers, consisting of local members who lived in Hancock or had come up from the mill and smelter towns along Portage lake and Torch lake, including Dollar Bay, Mason, Mills Station, Linwood, Hubbell and Lake Linden. No further stop was made until Calumet was reached, although the passengers had the opportunity in passing to see at a distance the Quincy mine on the hill just above Hancock, and its new north branch, the Mesnard, where the Quincy's No. 8 shaft, developed to a depth of 3,500 feet in the past eight years, is situated; the old Franklin, which has reached a venerable age and is still producing; the Franklin Junior, which during the last few months has developed at a depth of 2,000 feet on the Allouez conglomerate lode copper values that are stated by the management to be equal to the Tamarack's average values on the Calumet conglomerte; the Rhode Island, which is still striving to discover pay ground on the Quincy amygdaloid and Allouez conglomerate lodes and is waiting expectantly the outcome of neighboring explorations on the Kearsarge amygdaloid, also traversing its territory; the Tecumseh, where an 800-foot shaft has been driven since spring and disclosed enviable openings on the Kearsarge lode; the old Osceola branch of the Osceola Consolidated, which the management now states, after many years of a productive career, is in a position unequalled in the past for possibilities; and finally the imposing lines of shaft houses of the Calumet & Hecla Mining company on the Calumet conglomerate and Osceola amygdaloid lodes.

At the Calumet depot the members of the Institute were met by their fellow-members living in that section of the district, including President James MacNaughton. The party walked the half-mile distance to the Tamarack No. 5 shaft, which was the first point of interest to be visited, passing near the same company's No. 1 and No. 2 shafts on the way. From No. 5 the company's other two shafts, No. 3 and No. 4, could be seen, but they were not visited.

The Tamarack possesses the two deepest vertical shafts in the world, and a few hundred feet away is the Red Jacket shaft of the Calumet & Hecla, ranking third in depth. The three shafts form almost an equilateral triangle, all points of which were readily visible from No. 5 shaft and around which one could walk in less than half an hour.

The deeper of the Tamarack's two shafts in this trio, and therefore the deepest vertical shaft in the world, is No. 3, at the North Tamarack branch of mine, its measurement being 5,200 feet. To the south of No. 3 at a distance of about 4,000 feet, is No. 5, in the new territory of the old Tamarack branch. It ranks as the second deepest vertical shaft in the world, its measurement being 5,080 feet from the collar to the bottom level.

The surface equipment at No. 5 shaft has many features of unusual interest. The shaft has five compartments, one of which is for pipes and ladders and the other four are for general hoisting, having their cages balanced in two pairs. The shaft is equipped with two giant hoisting engines of the Nordberg type, the two being duplicates. Each has four inclined direct-steam cylinders. A unique feature of these hoisting engines is that they have no pits in which the drums may rotate but have pillow blocks sufficiently high to carry the drums entirely above the ground level. This gives the machinery an unusually imposing appearance. This shaft's surface equipment also includes one of the finest air compressors in the copper country, its capacity being about 100 drills.

The remaining active shafts of the Tamarack are Nos. 1 and 2 at the old branch, which are used for rock hoisting, and No. 4 at the North branch which is used for water hoisting.

In connection with the Tamarack it is interesting to know that the Osceola amygdaloid lode is also operated with a degree of success at several levels through the Tamarack's vertical shafts. This lode is parallel with Calumet conglomerate underlying it at a distance of 730 feet perpendicular to the dip. The vertical shafts therefore penetrate the Osceola amygdaloid lode some distance after passing through the Calumet conglomerate lode.

The Tamarack's principal source of production, however, is the Calumet conglomerate lode. This was found well charged with copper both in No. 1 and No. 2 shafts, which were the original openings, and in No. 3 shaft of the North branch, which was opened subsequently. No. 5 shaft during the first few years of its career opened ground of rather indifferent value, but during the last two or three years it has improved materially and is now maintaining very successful operations.

After sufficient opportunity to examine all that could be seen on surface at No. 5 Tamarack, the Mineral Range special was found to be waiting there for the Institute. The reason that it had not run directly to the shaft in the first place was a congestion of rock trains in the yards, which made it impracticable. This train carried the visitors out to a point near the Calumet & Hecla's private railroad, the Hecla & Torch Lake, where an improvised "special," provided with plank bench seats on a train of flat cars, was waiting to take the party. The kindness of the management in thus caring for the visitors to the best of its ability, this road not being provided with passenger cars, was much appreciated, as a long walk was avoided by the use of this "special,"

### THE RED JACKET SHAFT.

The Institute was carried next to the Calumet & Hecla's Red Jacket shaft, one of the three points in the triangle of the world's deepest shafts, already mentioned. This shaft has six compartments, the two easterly ones containing two Kimberley self-dumping skips operated in balance for hoisting rock, the two center ones containing two tanks operating in balance for hoisting water, each tank with a capacity of 3,000 gallons, and the two westerly ones containing two cages operating in balance, for handling men and material.

The Kimberley skips are built to dimensions that will contain nine tons of rock each, and about 7½ tons are hoisted at a load, leaving an ample margin of safety, that prevents any danger from rock falling over the edge of the skip into the shaft.

The hoisting of the rock and water is done by the Whiting system, in which the cable, carrying its two balanced loads of rock or water, as the case may be, passes four times around a pair of tandem sheaves. These sheaves are actuatel by triple expansion Leavitt engines. The tension of the cable is maintained by passing it out through a long gallery or tail house and around a tail sheave, where the proper tension is exerted.

The engines for rock and water hoisting are both in one engine house. The engine handling the cages for men and material, which is in a separate engine house, has also the Whiting system of hoisting, but this is to be supplanted by a drum hoist.

The Red Jacket shaft is sunk on the hanging wall or west side of the lode at a point nearly a mile from the outcrop.

The lode has an incline of approximately 38 degrees from the horizontal and the Red Jacket shaft encounters it at a depth of 3,300 feet. The copper is won from the formation below this level, which is the fifty-seventh, through crosscuts extending westward to the lode at distances of three levels apart.

The bottom level of the shaft is the eighty-first, and the crosscut extending to the lode at that depth encounters it approximately on the line where it passes from the Calumet &

Hecla ownership through the vertical boundary plane into the Tamarack property lying to the westward.

The levels tributary to Red Jacket shaft but which are not connected with it by crosscuts handle their rock downward through sub-shafts on the plane of the lode. In these sub-shafts traveling platforms are operated in balance and actuated by power, and upon these platforms, which present a horizontal plane, the tram cars are run, then lowered to the level connected to the shaft by a crosscut and finally trammed out to the shaft, where their contents are emptied into large receiving bins built of heavy boiler plate. These bins have apron chutes through which the rock is discharged in a very simple manner into the Kimberley skips.

A notable and interesting feature connected with the Red Jacket shaft but which the visitors were unable to see is the "slope" or sub-shaft extending from the fifty-seventh level due north on the plane of the lode for the purpose of winning the copper from five forty-acre tracts through which it will ultimately penetrate.

The drift at the fifty-seventh level on the conglomerate lode extends northeastward to the limit of the Calumet & Hecla's property, a distance of 2,700 feet from the Red Jacket shaft. This drift at a point approximately 1,800 feet from the Red Jacket shaft enters the most southerly of these five forties.

Another opening known as the footwall drift parallels the lode drift on a line 25 feet eastward in the footwall of the conglomerate, running for a distance of 2,100 feet, which carries it 300 feet into the most southerly of the five forties.

It is from the terminus of this footwall drift that the slope or sub-shaft begins, raking northward on the lode at an angle of 28 degrees from the regular course of the other incline shafts, and thus flattening its pitch to approximately 22 degrees from the horizontal.

By reason of the flatness of this incline the rock will be drawn upward through it in tram cars which will continue their course on along the horizontal floor of the footwall drift to the

Red Jacket shaft, where their contents will be discharged into the rock bin for dumping into the Kimberley skips.

Thus there will be only one transfer in bringing the rock from the extremity of the slope or sub-shaft to surface. The object of the footwall drift is to furnish an avenue for the transportation of rock between the slope and the Red Jacket shaft, without interrupting operations in the fifty-seventh drift on the lode.

The slope, starting as it does at a point 25 feet in the footwall of the lode, will maintain that position relative to the lode throughout its entire depth, thus eliminating the necessity of shaft pillars and leaving the entire lode free for extraction. The territory of the company's property will permit the sinking of this slope for a distance of more than 5,000 feet, thus making a haul of approximately two miles from its extremity to surface when it finally reaches its maximum length many years hence.

The slope has reached the sixty-first level, a length of over 1,000 feet from the fifty-seventh level, and according to the report of President Agassiz, some excellent ground has been developed by it. It is also officially stated that the general character of the rock tributary to the Red Jacket shaft has improved somewhat.

From the Red Jacket shaft the Hecla & Torch Lake "special" carried the Institute to the Superior power house, in which are located the Superior, Mackinac, Baraga and other engines, representing a combined capacity of nearly 15,000 horsepower.

The Calumet & Hecla's mechanical equipment possesses limitless interest and even a comprehensive summary of it could not be presented in a single article of these limitations. The Superior power house is the central point of attraction. Its Superior engine is of the vertical triple expansion Leavitt type, having three cylinders and a capacity of 4,000 horsepower, which is used both for the hoisting and air compressing. Its Mackinac engine is of the vertical triple expansion Leavitt type, having four cylinders and a capacity of approximately 7,000 horsepower, which is used for actuating a six-cylinder two-stage 500-drill set of Nordberg air compressors.

By the arrangement of grooved drums, which serve as balance wheels for the Superior and Mackinac engines, a rope drive may be installed which will permit either engine performing the functions of its mate in case of accident. This same system of arranging for duplicate and even triplicate service from various engines extends to every shaft on conglomerate lode, so that any engine may be shut down for weeks at a time if necessary without affecting the rock output.

Near the Superior engine house a transformer house has recently been erected where the electricity from the company's 10,000 horsepower station at Lake Linden is received and distributed to various points on surface and underground for hoisting, pumping, rock crushing, shop work and general motive power.

It was impossible, on account of time limitations, for the Institute to visit any of the other shafts of the Calumet & Hecla, but their positions and functions were carefully explained to those not familiar with the operations of this giant company. The active shafts on the Calumet conglomerate lode, enumerating from the north southward, are respectively Nos. 5 and 6 Calumet, which together comprise a two-skipway opening, No. 4 Calumet, No. 2 Calumet, No. 2 Hecla, No. 3 Hecla, No. 6 Hecla, No. 7 Hecla, No. 8 Hecla, Nos. 9 and 10 South Hecla, which together comprise a two-skipway opening, and finally No. 11 South Hecla, making a total of 12 inclined shafts, which command a length of approximately 13,200 feet on the strike of the lode.

Stepping across eastward from No. 11 shaft, the Calumet & Hecla's southerly active opening of the conglomerate lode, one encounters at a distance of 730 feet No. 13 shaft, which is the most southerly opening of the Calumet & Hecla on the Osceola amygdaloid lode. Ranging northward from that point are respectively Nos. 14, 15, 16 and 17 shafts, all on the same lode and all of which are active, excepting No. 17. President Agassiz announcing in his recent report that activity would also soon be resumed there. The copper returns from the company's Osceola lode shafts are very satisfactory.

From No. 17 shaft another tramp to the eastward for a distance of 2,200 feet will bring one to the line of the Kearsarge lode, and there will be found the Calumet & Hecla's most northerly opening on this famous copper-bearing amygdaloid bed. The company has opened three shafts thereon which, enumerated from north to south, are Nos. 19, 20 and 21 shafts. The ground developed on the Kearsarge lode by the Calumet & Hecla so far has not been better than fair but its openings are not yet extensive nor its depth great.

Special interest attaches to No. 4 Calumet shaft, on the Calumet lode, by reason of its being the deepest inclined shaft in the world. The measurement from its collar to its lowest level is 8,100 feet and from a drift at that level a winze extends downward for an additional distance of 190 feet to the extreme corner of the company's property. This gives a total depth on the incline of the lode of 8,290 feet. No. 4 shaft passes by the Red Jacket shaft, about 400 feet from the vertical opening, at the fifty-sixth level.

In recapitulation it may be said that the Calumet & Hecla's properties at Calumet consist of three distinct mines, distinguished by their location on three cupriferous lodes, one a conglomerate and two amygdaloids. There are 20 operative shafts, of which 12 operate in the Calumet congolmerate lode, one of these, the Red Jacket shaft being vertical, while five operate in the Osceola amygdaloid lode and three operate in the Kearsarge amygdaloid lode.

After the sight seeing for the afternoon was over the members of the Institute dispersed for supper at the hotels, cafes and clubs in Calumet. In the evening the assemblage gathered in the Washington school hall to listen to papers and discussions and to transact business. (The account of this meeting is contained in the minutes.) Following the meeting a special train was boarded at the Mineral Range depot for all those who wished to return to Houghton.

SECOND DAY'S ITINERARY.

At 9 o'clock on Thursday morning, August 9, the Institute departed on a special train from the Mineral Range railroad depot in Houghton for a trip over the county line into Keweenaw county, to visit the Mohawk, Ahmeek and Allouez mines on the Kearsarge lode.

This lode is justly celebrated by reason of its being the greatest copper producing formation that the world has thus far developed. There are today nine mines actively engaged in producing copper from its lode, besides several actively developing properties. The nine mines contain 20 producing shafts, whose daily capacity may be safely estimated at 500 tons of mill rock each, representing an aggregate of approximately 10,000 tons of rock shipped from this lode per day. Assuming that this rock will contain an average of one per cent metallic copper, or 20 pounds of metal to the ton of rock, this rate of shipment represents a production of 200,000 pounds of copper per day from that source.

While the beginning of production from the Kearsarge lode dates back to about 1880, it produced only in an erratic manner during the first dozen years of its existence and was quite an uncertain quantity until about eight years ago. Since then its career has been indeed meteoric.

Previous to 1897 there were but two mines operating upon the Kearsarge lode, namely, the Kearsarge and the Wolverine. By 1898 these properties had been sufficiently developed to demonstrate the unquestionable value of the formation, and the accidental discovery of copper by a woodchopper on Fulton hill was immediately followed by the organization of the Mohawk to work the lode at a point nearly four miles north of any operations hitherto conducted upon it.

Co-incident with this discovery and the growing success of the Wolverine and Kearsarge mines came the copper boom of 1898, and this not only resulted in the successful promotion of the Mohawk but also in the resuscitation of interest in the Centennial, which had been plodding hopelessly for 30 years or more in an attempt to discover copper values in the Calumet conglomerate lode on its property, but which then turned its attention to opening two shafts on the Kearsarge amygdaloid lode. The Centennial carries this lode under its entire area of one square mile on an incline of about 38 degrees, permitting its operation to a depth of over 9,000 feet on the plane of the lode.

The Osceola Consolidated, which had then only recently obtained control of the Kearsarge mine and named it the North Kearsarge branch, also opened a new mine on the tract lying between the Wolverine and Centennial, naming it the South Kearsarge branch, making the fifth mine to be opened on the Kearsarge lode.

By the time the copper boom had subsided in 1902 the Kearsarge lode had fairly entered upon its notable achievements, and the Ahmeek, which 25 years previously had attempted to develop profitable ground on the Kearsarge conglomerate lode, but which failed, resumed activity by searching for the Kearsarge amygdaloid. The results were successful beyond expectation and an unusually rich portion of the lode has since been developed.

It is worthy of note that if one of the early exploratory shafts on the Ahmeek, sunk to a depth of about 35 feet in the overburden and then abandoned before reaching the rock, had been carried down 15 feet farther, it would have bottomed squarely on top of the richest part of the Kearsarge amygdaloid lode. It is therefore evident that the Irishman's advice should be taken, "always to sink about 20 feet farther, after you have stopped."

Almost simultaneous with the beginning of activity at the Ahmeek the Allouez transferred its energies from rather indifferently successful explorations on the Allouez conglomerate lode to the development on the Kearsarge lode. It went about this undertaking in a very courageous manner and was richly rewarded for its temerity.

The Allouez property does not carry any portion of the outcrop, and therfore it was necessary to sink a distance of 1,390 feet through barren rock before the lode was encountered. The shaft is sunk from surface to the lode at an angle of ten degrees from the vertical. When the lode is reached the shaft alters its incline in conformity with that of the formation, the change in angle occupying a length of about 75 feet in the shaft. The skip travels over its variably inclined track with an ease and steadiness that cannot be excelled.

The steeper portion of the shaft is provided with back runners set at a distance of only about one-eighth of an inch from the skip wheels, yet so closely does the skip ride to its track that the back runners are rusted and do not show the slightest abrasion.

The properties thus far mentioned as operating on the Kearsarge lode have been enumerated in their chronological order, according to the dates on which they began activity. Enumerating them in rotation from north to south, and giving the complete list, they are: The Gratiot, owned by the Calumet & Hecla, with two shafts under development; the Mohawk, with five shafts; the Ahmeek, with two shafts; the Allouez, with one shaft in service and one shaft under development; the North Kearsarge, with two shafts; the Wolverine, with two producing shafts and one man shaft; the South Kearsarge with two shafts; the Centennial with two shafts; the Calumet & Hecla with three shafts, as already described on a preceding page; the Tecumseh with two shafts; and the Caldwell, controlled by the Calumet & Hecla, with two shafts under development. The lode has also been located by means of diamond drilling in its southerly stretch on the Laurium, the Rhode Island and the Franklin Junior. Explorations on the Kearsarge lode northward from the Gratiot have been undertaken, but success there has not yet been attained.

Special interest was taken by the Institute members in the

Ahmeek's surface equipment, which was at that time nearing completion for heavy production. There are two shafts 1,440 feet apart, and the power and crushing plant is situated midway between them. At each shaft there is nothing but a small rock house of sufficient capacity to provide a dump. The shafts are connected with the central plant by means of trestles, over which the rock is trammed mechanically after it is dumped from the skips. There is one boiler plant, to accommodate eight boilers and provided with a 150-foot steel self-supporting brick-lined stack; one power house containing a hoisting engine, compressor and electric generator; another power house containing the hoisting engine for the other shaft, a crusher house; and a circular rock house. The boiler house is between the two power houses and it is provided with a coal trestle which runs the fuel direct to the furnace room. The hoisting engines have duplex steam cylinders and double conical drums, each capable of winding 5,000 feet of cable.

The rock, after it is trammed from the shafts, is dumped automatically over the grizzlies in the crusher house and the portion remaining on top of the screen goes by gravity through feeding chutes to the rock crushers, one man at each crusher being all the attendance required. The building is so low that these crushers are set on concrete foundations, and thus all vibration is eliminated. The rock, reduced to milling size, all flows to a hopper which is accommodated by an excavation for the purpose in the earth in the center of the building. This hopper forms the boot of a link belt elevator extending at an angle of 45 degrees to the top of the circular rock house. This structure is of steel and stands on a concrete foundation of sufficient height to permit the rock trains to pass through it. The diameter of the building is 32 feet, equivalent to the length of a rock car. The cars when spotted are filled from chutes in the bottom of the bin portion of the rock house operated by levers in the hands of a man whose station commands a view of the entire length of the car. In this way the cars can be filled at the rate of more than one a minute, and an entire train load can be filled in 15 minutes to half an hour. All machinery except the hoisting engines is operated by electricity generated in the power plant.

A party of a dozen members of the Institute, through the courtesy of the Wolverine Mining company's management, was conducted underground, Chief Mining Captain William Pollard acting as guide. This portion of the party did not reach Houghton until 6 o'colck in the evening, coming in on the street cars. The special Mineral Range train carrying the main body of the Institute ran directly to the Ripley Baseball park, on the shore of Portage lake and just across the water from Houghton. There the members were given the courtesy of the park and witnessed a game between teams of the Northern-Copper Country league or "Nancys" (NN-C-CY), as they are called. The courtesy of the ferry was also extended to the Institute for the ride to Houghton. The evening session was held in the court house at Houghton. (The proceedings of the session will be found in the minutes.)

### THIRD DAY'S ITINERARY.

At 8 o'clock on Friday morning, August 10, the main body of the Institute departed on a special train from the Copper Range depot in Houghton for Redridge, where the Atlantic and Baltic stamp mills are located, on the shore of Lake Superior at the mouth of the Salmon Trout river. The first point of interest visited was the steel dam with concrete foundation across the river there, to conserve water for use in the two mills. It possesses unusual interest and is technically described in the Engineering News, issue of August 19, 1901, a cut of same is shown in Vol. VII.

From the dam the Institute went to the Baltic stamp mill, which was the only mill visited, as it is typical of all the others, the practices varying only in minor details.

From Redridge the Copper Range special train carried the Institute to Painesdale, where the surface plant of the Champion mine was inspected, and then to Baltic, where the new

No. 2 shaft rockhouse was explained in detail by General Manager F. W. Denton. A party was also carried underground there, the object being more particularly to examplify the man-cages in which the underground men are carried to and from their work. These cages are two-deck and enclosed with heavy wire screens. The incline of the shaft being about 70 degrees, it is readily adaptable to this method of carrying the men.

Baltic No. 2 shaft is within about 500 feet of the original discovery point on the Baltic lode, made in 1883, but whose value previous to eight years ago was looked upon as a mere fancy, incapable of commercial posibilities, by those who knew of its existence and who were few indeed.

Because of its very steep incline, which is entirely out of conformity with any other copper-bearing lodes in the district, its discoverers started their openings at too flat an angle and soon ran into the hanging wall. It was 14 years after the discovery before any one thought enough of its possibilities or cared enough to investigate its value. Then the oncoming copper boom, which simultaneously was an important factor in the financing of developments on the Kearsarge lode, as already described, gave new life to interest in the district south of Portage lake. The old "Six Mile Hill" property was revived as a result. It was named the Baltic in opposition to the Atlantic and the Pacific, names already carried by neighboring properties, and from that the copper bearing lode which traverses the property was named. The Baltic lode and the Kearsarge lode were thenceforth twins in their development and position in public favor.

The discovery of commercial possibilities in the Baltic lode was made on the present Baltic property by Captain W. A. Dunn at the site of the earlier disclosures of copper, which had been made by Captain John Ryan. Within a very short time its value was recognized, and the Champion began a search which resulted shortly after in the disclosure of the lode on surface about the same time the Trimountain began explorations with a diamond drill yielding satisfactory results within a short while.

The discoveries were all eminently satisfactory, and the growth of the three properties concerned in the early disclosures—the Baltic, Trimountain and Champion—ran a close race. Each has four shafts, which today are developed to a depth averaging about 1,200 feet. The history of the lode has been a record of success from the beginning, and promises in time to rival the Kearsarge lode in extent of territory and copper output.

About four years after the beginning of development on the Baltic lode the Baltic property, which was organized as an independent company, was absorbed by the Copper Range Consolidated, a large securities company which had been organized to hold the ownership of the Copper Range railroad, one-half interest in the Champion mine, extensive mineral territory and stamp mill and smelter interests. Shortly after that the Trimountain mine was also absorbed by the same ownership, thus putting practically the entire output of the Baltic lode under one control, the only foreign interest being the ownership of one-half of the Champion mine by the St. Mary's Mineral Land company.

### SOUTH RANGE EXPLORATION.

Simultaneous with the development of the three mines already described, there began on the South Range a general campaign of exploration, which is still maintained, though unattended by success thus far excepting at the Winona, where quite an extensive amount of copper ground has been opened. The King Philip, lying immediately south of the Winona, has also obtained good diamond drill cores and is sinking rapidly in the expectation of developing good copper ground. These two properties are under one control.

Other points of exploration on the South Range, enumerating from the Champion southward, are the Globe, under option to the Copper Range Consolidated; the Challenge, owned by the St. Mary's Mineral Land company; the Elm River; the

Wyandot; and the Lake. These are on lodes which have not been fully identified, but are on the general trend of the Baltic lode.

Northward from the Copper Range Consolidated properties a most successful development of copper values has been made on the Baltic lode by the Superior Copper company, which began exploring about two and a half years ago. It has two shafts in progress, one of which is down 400 feet, with good copper values in evidence. The Calumet & Hecla has acquired an interest in this property and holds an option on the control of the capital stock.

The Isle Royale, to the north of the Superior, and the Atlantic to the south, are exploring on the Baltic lode, but their work is still unattended by success.

Two features of unusual interest engaged the attention of the Institute during its trip to the south range mines. One of these was the 100-drill Nordberg air compressor at the Champion. This compressor holds the world's record for efficiency among steam engines. It is soon to be made the subject of a technical paper by Prof. O. P. Hood, of the Michigan College of Mines.

The compressor is equipped with quadruple steam cylinders and a regenerative feed-water heating system which has produced some remarkable results. The water is raised from a temperature of 72 degrees at the initial point of regenerative heating to 341 degrees at the point where the feed water enters the fuel economizer. This increase in temperature is secured by permitting steam which has already performed its function to mingle with the feed water at several stages, gradually bringing it up to the maximum temperature. In the fuel economizer the temperature of the steam is raised from 341 degrees to 397 degrees before entering the boiler.

The other feature of unusual interest was the filling system, as practiced at the mines of the Copper Range Consolidated. In this system the lode is cut out to full width from foot to hanging, and two parallel walls of rejected mine rock are built up seven feet apart and seven feet high. These artificial walls, with the lagging which spans them on top, constitute the transportation drifts of the openings. Into these artificial walls recesses are built at fixed spaces apart, these constituting the lower terminals of chutes down which selected copper rock is to be thrown. These recesses are timbered up to the top of the wall and each is provided with an apron, that serves to check the flow of copper rock when raised and feed it into the tram car when lowered.

Of the rock broken down in the lode, approximately 50 per cent. is rejected, the remainder being sent to surface and to the stamp mills. The rejected rock fills in between the artificial walls of the transportation drift and the foot wall and hanging wall of the lode, and after this is filled in to the top of the artificial walls, the rejected rock fills in the entire voided space from foot to hanging. As the broken rock occupies approximately twice the space of rock in place, the rejected material serves, as a rule, to fill up the voided portion of the lode. If there is not enough, the barren rock of either wall of the lode is blasted down to make up the deficiency. If there is too much the surplus is hoisted to surface and thrown on the waste dump.

As the surface of the filling material rises the chutes, whose lower terminals are the recesses in the walls of the transportation drifts, are carried up simultaneously. These are built of the larger pieces of rejected rock and, like the walls of the drift, are laid up without mortar. The sorters dump the pay rock down the chutes, both by tossing it in by hand and by wheeling it in a barrow. The distance between the chutes is so spaced as to make the hand practice generally possible.

The filling material is constantly maintained at such a level that its surface will serve as a floor from which to attack the roof above. In this way the posts for the air drills always find firm anchorage without timbers and the miners have a solid floor upon which to work, thus removing the dangers of falling.

When finally the limit, if territory tributary to a drift is reached, either between the shafts or at the boundary of the property, the stope below is opened through the floor into the drift above, it being assumed that the drift and stope above have become exhaustetd. The floor is thus entirely extracted and the filling material from above comes down and fills the remaining space below as the work recedes toward the shaft. This feature of the filling system is admirably illustrated in the accompanying sketch by E. N. Wold, a student in the Michigan College of Mines at Houghton. This sketch also shows most of the other features of the system. There may be seen two dead chutes in exhausted portions of the workings, as well as a live chute with a tram car standing on the track below it. The accompanying photograph of a model in the Michigan College of Mines, illustrating a cross section of the lode and the details of the filling system is equally instructive.

The Institute, after leaving the Baltic mine, was carried to the Michigan smelter, which has been in operation two years. It is on the shore of Portage lake, two miles west of Houghton. The plant is on the escarpment and at the base of a high hill, along the crest of which runs the Copper Range railroad. This provides for ideal facilities in handling the mineral, fuel and fluxes. The smelter has six furnaces, one 16x40 feet, two 16x36 feet, two 14x23 feet and one 15x18 feet. This allows an amplitude of spare furnaces, giving the plant a capacity of over 10,000,000 pounds monthly, or approximately 100 per cent. above the requirements, which at present are less than 5,500,000 pounds.

The ladling and casting of the refined copper is entirely mechanical. There is a constant stream of molten metal flowing from the furnace into a large ladle with a tilting device, and this discharges into the moulds, which are attached to a machine in the shape of a large horizontal wheel. This wheel is under the control of the same operator who manipulates the tilting of the ladle, and he stops and starts the mechanism at will.

A published record of the performance of the smelter states that there was cast from one furnace in the regular run of work a charge containing 292,000 pounds of refined copper in seven hours, or at the rate of 750 pounds a minute. To do this six men were required to operate the furnace and casting machinery and four men were employed inspecting, sorting and loading. The bars of refined copper are cooled by water and dumped within 30 seconds after the molten metal is poured from the mechanical ladle.

Electricity is used for power in all available places, including the driving of the casting machinery, the operating of three locomotives throughout the yards for handling fuel, mineral, fluxes, copper and other material, and an electric traveling crane that is accessible to all of the furnaces.

Steel cars are used in conveying the mineral from the mills to the smelter and they discharge their contents into large steel bins. These are on the high bluff back of the smelter, on the main line of the Copper Range railroad.

The Institute was fortunate in reaching the smelter just before casting began, and the members were thus enabled to see this interesting process. From the smelter the Copper Range special returned the party to Houghton for dinner in time to allow those who had so planned to depart on the afternoon trains for their homes, this being the last day of the Institute.

Quite a number of the members substituted other trips in place of the one to the south range mills, mines and smelter, some going to the Quincy mine on the hill above Hancock, others to the Quincy smelter on the shore of Portage lake, opposite Houghton, and still others to the Lake Superior Smelting company's plant at Dollar Bay, the Quincy stamp mill at Mason, the Tamarack and Osceola stamp mills at Mills Station, the Calumet & Hecla smelter at Hubbell and the Calumet & Hecla stamp mill at Lake Linden. A small party substituted for the other program a trip to the Globe shaft of the Copper Range Consolidated, where an interesting problem in shaft sinking through 250 feet of overburden is being worked out.

A few other members of the Institute made a trip through Ontonagon county, where four producing mines are located. These properties, enumerated from north to south are: The Adventure, with two active shafts; the Mass, with three shafts; the Michigan, with three shafts; and the Victoria, with one shaft. The Copper Crown, lying beyond the Victoria, is exploring, and the Nonesuch, still further to the south, has recently been optioned to the Calumet & Hecla, which company is diamond drilling and unwatering the old workings. Activity has also recently begun at the White Pine and Carp Lake properties.

From a mechanical and economic standpoint the most interesting feature in Ontonagon county is the Taylor hydraulic air compressor at the Victoria. The air is compressed by being entrained or sucked in by water, which plunges down at high velocity through five-foot cylindrical vertical shafts. The air is trapped in a large chamber, stoped out of the sandstone at a depth of 355 feet, while the water flows outward through a low tunnel and upward through a discharge shaft. The discharge of water is on a horizontal plane seventy-two feet below the inflow.

The pressure of air is maintained at from 113 to 123 pounds and is used for all power purposes that ordinarily consume steam, including rock hoisting, stamp-head operations and shop motive power, besides the machine-drill operations. The compressed air is unusually dry, because the surplus moisture ordinarily attending the compression of air enters into the water by which the air is compressed in the Taylor system.

The most satisfactory mining results thus far obtained in Ontonagon county have been at the Michigan, where the Branch vein was unexpectedly encountered, heavily charged with mass and stamp copper. This Branch vein has a dip of about 58 degrees, connecting the Minnesota conglomerate and the Calico vein, which both have a dip of 47 degrees. The

Branch fissure makes into the Calico lode at the fifth level its upward trend and into the Minnesota, near the fourteenth level in its downward trend.

All of the producing mines in Ontonagon county have their stamp mills completed, with the exception of the Michigan, which is just now beginning construction on its mill.

This description of the itinerary of the Lake Superior Mining Institute in the copper country of Michigan would be incomplete without reference to the great activity that has been inaugurated in the more remote part of Keweenaw county within the last year, although the members of the Institute were not able to include that portion of the peninsula in their trips. In November, 1904, C. A. Wright, of Hancock, began the acquisition of mineral lands in that county by option and purchase for a new company organized by him and called the Keweenaw Copper company. Later he also acquired extensive lands by option for transfer to the Calumet & Hecla Mining company. Vast tracts of unexplored or inadequately explored lands are now controlled in that section of the copper country by these two companies, and five exploratory shafts are being sunk, one by the Keweenaw Copper company on its Medora tract and four by the Calumet & Hecla on its Delaware tract. In addition to this there are half a dozen diamond drills at work on the lands of the two companies.

The Keweenaw Copper company also owns the entire capitalization of the Keweenaw Central railroad, now under construction from Lac La Belle to Calumet, furnishing the most complete transportation facilities for the newly developed country and bringing it into the closest touch with the milling and smelting centers of the district.

# MINUTES OF THE MEETING.

## EVENING SESSION, WEDNESDAY, AUG. 8, 1906.

The evening session was held at the Washington school, Calumet, Mich., Wednesday evening, August 8, 1906. The meeting was presided over by Mr. James MacNaughton, president, who first addressed the Institute.

Members of the Lake Superior Mining Institute and Gentlemen: You are very welcome to the copper country, and in welcoming you to the copper country on this occasion, the twelfth annual meeting of this Institute, I wish to congratulate you first upon the large attendance, indicating as it does the interest taken in the Institute matters, and secondly, the interest taken in the profession you are following.

I wish also to congratulate you upon the prosperous conditions that are obtaining in the mining industry of this district today—possibly more prosperous than ever before. I think when the figures are footed for the shipments from the various iron ranges of the Lake Superior district they will amount to more than ever before in its history, and I feel confident that the same will be true of the copper district. We will experience setbacks undoubtedly in the future, but they will be only temporary, as we have experienced them in the past, and I feel very confident that this entire mining district can look forward to even greater prosperity and greater success than it has achieved in the past. You are to be congratulated on the whole situation as it exists now. I shall not take up any of your time by further talk, and the first paper on the program is a paper by Dr. Lane, "The Geology of Keweenaw Point." We would like to hear from Dr. Lane.

MR. LANE: Mr. President and Gentlemen; I do not think it is necessary, you having the paper right before you, to read it in full, but I presume a few remarks may be desirable by way of giving you a chance for discussion.

I would like to call your attention to the fact that the Lake Superior basin, so-called, is really a basin. It is really a down-curve in the crust of the earth, and there are few such. Being a down-curve, there never could have been any great accumulation of stress except down, therefore it must have been always curving down during geological time. At the same time, if the earth is sinking, the earth must give and apparently it has given, so that we have the core of this basin thrown out on either side. On this side we have the copper range, and we have a similar ridge on the other side. The beds dip to the north as you have seen around here, so that the Calumet mine, where you are standing, is reached by the vertical shaft of the Tamarack mine to the northwest of us.

When we consider the character of the flows which make up the copper bearing rocks, we find they are mainly lava flows, or flows of molten rock. Here and there we find through them streaks of sedimentary rocks, sandstone and conglomerates like the Calumet conglomerate, but the main rock was once molten, and as it is in making candy or maple syrup, the bubbles worked to the top and made an open porous scum, which, when it is filled with white minerals of one sort or other, is called amygdaloid.

Now before these beds were filled they were certainly much more porous than the main mass of the rock which was under greater pressure and solidified more slowly, and I want to call your attention to one thing, as you go towards the center of these lava flows the grain gets coarser. This fact helps us in locating amygdaloids.

Now suppose you have a layer cake, composed of solid layers of cake, and in between it whipped cream, and you tip that up on one side, there is going to be some sliding. The whipped cream will pass for the amygdaloids and the heavier cake will pass for the traps. That is what we have had here—we have had a good deal of sliding and settling.

If you have a chance to examine any of the rock which comes directly from above Calumet conglomerate, you will find marks of slickensliding, showing that this is not merely the top of a conglomerate bed, but also a line of slipping and sliding. The chemical character of these rocks, of course, varies, but there is a very strong tendency to what might be called an average basaltic type, the chemical character of which is given in the paper.

Now there is a difference between the hanging wall trap and the footwall trap, as you have noticed in many of these lodes. The copper, I may say, has accumulated more or less in the amygdaloids. Naturally the sliding and the rearrangement will be most profound in these open and porous beds. There is where the copper has accumulated. Before this sliding took place, probably in the very process of cooling, the whiter minerals had a tendency to gather toward the top, and the augite, or darker mineral, to the bottom, so that the hanging wall trap is generally darker. The footwall trap directly below the amygdaloid is rather more feldspathic and rather lighter. In many cases this can be easily recognized.

I would like to call your attention also to the large crystals of feldspar which are floating around in the trap, which is the footwall of the Kearsarge lode. These are a very characteristic feature by which one can often recognize when you are just below the Kearsarge lode.

Now we have been working on the other end of the copper range near the Wisconsin line, north of Ironwood, and I expected at first there would be a repetition of the series in the ranges, near the north and south ends of Lake Gogebic, but it is not so; the south range rocks are not the same. There is a larger proportion of the trap, which is pretty fine grain. That whole black series of some thirty odd thousand feet of rock is apparently continuous. Now when we come to study out the Keweenaw series in detail, the work has been a good deal on the beds of conglomerate. Of the sedimentary beds there are only about eighteen important ones throughout the whole central part of the series. These have received numbers and also names. You will find on one of these maps a few of the characteristic conglomerates mentioned.

Commencing at the lowest part of the series, the first notable conglomerate is conglomerate known as 3, which is a little way, (about 160'). below the Baltic lode. Then skipping some beds there are conglomerates 6, 7 and 8, which go not far below the Isle Royale and the Winona mines. Then coming up a little there is a bed known as Wolverine sandstone No. 9, which lies 100 to 200 feet below the Kearsarge lode. And above that is the Kearsarge conglomerate, Nos. 10, 11 and 12.

Then you can easily remember the number of the Calumet conglomerate, because it is the lucky 13. And then a very persistent bed is the Allouez conglomerate, or the Albany & Boston, No. 15, which is now called Franklin Junior. That is about the only conglomerate outside the Calumet which has really amounted to very much as a copper producer. Then there are a number of others; one is No. 17, which was worked by a series of small mines in the early days out there at the point, and though there is some difference of opinion, I think this is not very far from the lode of the Atlantic mine.

There are of course a great many amygdaloids. The average trap bed will be anywhere from twenty to ninety feet thick. In rare cases there may be several hundred feet of trap and amygdaloid. The mines here, by vertical shafts and their crosscuts, have given the actual measurements of something over 5,000 feet, and if some diamond drill man will go to the bottom of these shafts, and go another 5,000 feet, he will probably get as near the center of the earth as we shall ever go.

Now I want to call your attention also to the matter of the source of the copper, though I suppose you are more interested in getting it than in knowing where it comes from. My personal feeling is that it is closely connected with this series of traps. We have not got to look in the heavens above nor the earth beneath for the source of the copper and the water that deposited it. In the sense of Emmons I suppose I might be called a lateral secretionist. By the way I notice Mr. Weed is here at this meeting, and has been writing of a very similar occurrence in New Jersey. I want to call your attention to the fact that these mines have salt water after you get down a short distance. Then if you go down, we will say, to about the 17th level, in opening up the level (and I stand open to correction, because many here know more about it than I do) there may be a good deal of water to begin with, and men will say, "I will show you where you can get some water on the 17th level," yet when you get down there it is gone. But what little water there is is liable to be salt. To begin with it is largely a solution of sodium chloride, but with greater depth it changes and becomes pretty nearly saturated with a solution of calcium chloride. I do not see any way in which there can be any circulation from without the formation and leave the waters thus stratified.

These amygdaloids in the first place must have been filled in some way either with volcanic gases or sea water. We will suppose for example's sake it was sea water, but as matter of fact it has been shown that volcanoes yield chlorine gases and hydrocarbons; thus it is easy to see how the chloride could be introduced in that way, and then the upper layers be washed out and be salt. But why water working up could stop at 1,000 feet is rather beyond me. It looks to me as if these salt waters had been in the formation since it was laid down. I do not mean to say there is no circulation, but the downward circulation has merely washed out the first 1,000 or two feet.

Now in regard to the matter of the ice age, I want to call your attention to one fact, and that is, you will find right around here, the Calumet shafts and in other places, good exposures of ice-polished rocks, and if you look sharp you will notice the ice motion is from Keweenaw bay.

The last ice age that came over this way (there was one earlier from the north) but the last one had its center in Labrador, came down Lake Superior and spread out over Keweenaw bay, so that the last ice age and the prevalent motion of the last drift around here is from the east toward the west. That, I think, will give you a sufficient abstract for discussion.

MR. MACNAUGHTON: We have taken occasion, in the course of the last two or three years, to get a strike of the ice marks in this particular district, and we found them very universal from east to west. In a few instances about ten degrees north of west, and very marked over a space of eight or ten miles.

Now we would like to invite any questions on Dr. Lane's suggestions. To those of you who are not familiar with the copper district I might say this, that Dr. Lane, when speaking of the Allouez conglomerate, on which the Boston & Albany mine, now the Franklin Junior, is working, is known here pretty generally as the western or northwestern limit of the copper deposit. I think today there are probably only two exceptions to that. There are only two properties working west of the Allouez conglomerate, and that is the Quincy and the Atlantic, and the proposed Hancock Consolidated. Otherwise all of the mines of the district are east of the Allouez conglomerate, except Franklin Junior which is in it. The old Allouez mine proper worked in Allouez conglomerate for a great many years and sold at fifty cents a share, with no takers, and now they have moved further east until they have got in the Kearsarge amygdaloid in this district. The Calumet & Hecla conglomerate intervenes between the Allouez on the west and the Osceola amygdaloid on the east. East of the latter is the Kearsarge, which is an important amygdaloid now, and one that has been worked over a longer stretch than any bed in this district. The Mohawk, Ahmeek, Allouez, North Kearsarge, Wolverine, South Kearsarge, Centennial and Calumet & Hecla, are now working on it. It is probably worked out to a greater length than any other bed in this district. Then still further east is found the Isle Royale and Baltic lodes. Although the Allouez and Centennial mines have worked for a great many years, probably for the last twenty-five or thirty years, neither one of them have been marked successes until they got on the Kearsarge amygdaloid. Now they are both having exceptionally good showings of copper. The Calumet & Hecla company has the same vein on a portion of its property, and is opening it up today with fair success. I suppose next in length to that is the Baltic vein on which is opened the Trimountain, Champion and Baltic.

I think we will have to invite these foreigners from the iron country to make a study of the geology of Keweenaw point, they may give us all pointers on the copper. We are under the impression there is a good deal of copper up here if we only know where to find it.

Is there any further discussion on Dr. Lane's paper?

MR. KELLY: I would like to ask a question. The gentleman in giving his abstract said that probably we were more interested in finding copper than in knowing how it happened to be in certain localities. I have not had an opportunity to read the paper—perhaps it is stated there, but I would like very much if Dr. Lane would give us some general idea as to how it happens that the copper is to be found in certain veins or layers, and not in others.

DR. LANE: I am afraid that goes into the realm of speculation, but I am a Yankee born, and therefore I am entitled to guess. I should guess off hand that when these volcanic eruptions took place there were times when the chlorine waters dissolved more copper. Even now we find in solution at times iron chloride and some copper chloride—not a very large amount. Then I think there was a certain amount of copper in a mineral known as Oliveine. You will find it in almost all of this trap. Oliveine when it is fresh is an olive color. Almost invariably this is altered to a red color. As to what precipitated them in the particular places where they occur is another question, but there are certain possibilities there which I suggest, because I honestly believe the mining people here are the only ones who can test them by watching.

We find there is lots of calcium chloride in the upper mine waters, and that the upper waters have more sodium carbonate and silicate. If these waters work down, they may very well re-act and precipitate calcium carbonate, a mineral we find everywhere, leaving sodium chloride in solution. In that same process of precipitation if there is any reducing agent there, why the copper can be easily thrown out, and we do find copper intimately intergrown with calcite. That the reducing agents, as Pumpelly suggested, were ferrous salts, though perfectly plausible, becomes unnecessary if we suppose carbon compounds originally present in lava or sea water. It is also true, as Mr. Heath has told me, that there are certain combustible gases in mine waters. Now, R. S. Chamberlin, of Chicago, has shown that lava contains a certain amount of combustible gas. That is an important reducing agent. The copper deposit may then show that gas laden water circulated that way. If I knew why they are in particular areas rather than others, I suppose I should be running a mine rather than state geologist.

MR. DENTON: Speaking of ice marks, I would like to ask Dr. Lane if he has observed the direction at the west end, for instance at Greenland or Rockland? At Winona, where it is difficult to determine the direction, I think it is nearly north and south.

DR. LANE: Very true. They would seem to have been on the other or lee side, and to have got the effect of that earlier movement from the northwest or Keewatin center. I imagine that the ice-marks there are a product of the earlier movement. It is beyond question true that at the Winona it is from the west of north.

MR. DENTON: Very slightly.

MR. MACNAUGHTON: If there are no further questions on Dr. Lane's paper, we will have a paper by Mr. Jackson on "Five Years of Progress in the Lake Superior Copper Country."

Mr. Jackson's paper with the discussion on same is published in another part of this volume.

This concluded the reading and discussion of papers for the evening. The committee on permanent badges reported that they had made a selection of a badge and that a number had been made up by Tiffany & Co., of New York, and were to be had by making application to the secretary. The price of the badges is $4.00 each which represents the actual cost to the Institute. The committee was on motion discharged.

On motion the president appointed the following committees:

Auditing Committee: Charles E. Lawrence, David T. Morgan and Charles C. Jones.

Committee on Nominations: William Kelly, George D. Swift, George A. Newett, George H. Abeel and F. W. Denton. Committees to report the following evening.

There being no further business to come before the meeting an adjournment was taken until Thursday evening.

## EVENING SESSION THURSDAY, AUGUST 9TH.

The second session was held at the Court House in Houghton, at 8:30 p. m., President James MacNaughton presiding. The first paper for the evening was prepared by Doctor Jones, of Vulcan, Mich., on the subject of "The Importance of the Ordinary Sanitary Precautions in the Prevention of Water Born Diseases in Mines." As Doctor Jones was called away just before the meeting, the paper was read by Mr. William Kelly, and was very interesting, bringing out considerable discussion. The subject is certainly a most important one, effecting as it does the miners in the iron and copper country, as well as those in other localities. The Institute can do no better work in any direction than that effecting the condition of the miner, and it is hoped that the subject will receive further attention from its members. The paper with the discussion is published in this volume.

MR. MACNAUGHTON: The next paper will be read by title only. "The Iron Ore Deposits of the Ely Trough, Vermilion Range, Minnesota," by C. E. Abbott, Hazel Green, Wis.

Since the meeting of last evening the subject of earthquakes has provoked a good deal of discussion, and numerous questions have been asked last evening and today on the subject. A great many of the questions could not be answered—those that I heard, at least. I think Mr. Kelly has some questions that he wants to ask.

MR. KELLY: Last night I listened to the discussion, and was very much interested in the question of "Man-made Earthquakes." I was not sure whether the speakers were talking about real earthquakes, or about crushing mine walls, or both, and after the meeting I tried to find out whether there were two sets of phenomena, or only one. Then I was told that there was something that seemed to most people in this neighborhood to be a real earthquake, and that it did not occur at the same time as the air-blasts at the Atlantic mine, but I understood that it occurred at the same time as the Quincy trouble. Tonight I have been told that the so-called earthquake took place at an entirely different time from either of the mine shocks. I would like therefore to know whether the latter is the case, or whether the three disturbances took place together, or two of them took place together, and particularly whether there has been a real bona fide earthquake as distinguished from the mine disturbances.

MR. MACNAUGHTON: I would like to call on Dr. Lane, if he is here.

DR. LANE: I am not a permanent resident, and therefore let somebody else answer as to how many earthquakes you have had here.

MR. MACNAUGHTON: Mr. Kelly's question was particularly as to whether we had the real thing here or not.

DR. LANE: Well, it depends on just how you define the real thing. I only speak of one point, and that is we have a very singular phenomena. In India a man named Smith—I think he spells his name S-m-e-e-d-t-h; something like that—has written a paper on the earthquakes in Mysore, and he makes a distinction between air-blasts, where the rock is falling off, and earthquakes. In air-blasts it snaps like a bulb of an electric light will snap sometimes. It is in a state of tension from the jar of the larger slip. Now an earthquake is a jar, and it does not make very much difference what starts the jar, whether it is the powder works down at Woodside blowing up, or whether it is a mine going down or whether it is a great earth movement, not made by man, but made by the mountain building forces. Now there have been disturbances of some kind in the copper country a number of times (for instance this year, Aug. 8, again in February and particularly May 26), and some of them have spread over a very considerable area. For example that earthquake up at Calumet, I don't know where it started from, but it smashed plate glass there and broke down chimneys, and as near as I can figure out it was only two degrees less than that at San Francisco, according to the scale used by the San Francisco commission. The earthquake at San Francisco was not the worst part of it, but the fire afterwards. Now I don't know all about these earthquakes, and I am glad of it, because if we did, we should stop investigating. I think we ought to have a machine to register everything of that kind, to tell how strong it was, and from what direction, and then we would be in some position to say definitely what they are, whether the rock itself is under compression, and the yielding of the mines is merely a symptom of a wide-spread expression. Last night we did agree that in the Atlantic movement there was a certain amount of compression and moving of ground near the mine, which they could not account for by anything farther back, as I understood it; that is, taking the track which was running down from the mine to the mill, there was a buckling at the mine and there was not enough compensatory stretching anywhere else, indicating that the two sides of the mine moved together. Now, as I say, that refers to the Atlantic mine shocks of May, which were apparently a strictly man-made earthquake. The Calumet shocks may have been something else. It certainly was much more widely spread, but both those shocks were felt in my geological survey office, which is over three miles from the Atlantic mine, and of course, a good many more from Calumet. Other people may have much more light on this subject, but I don't think we know definitely yet all about the cause of these things.

DR. GEO. A. KOENIG: I would like to ask Dr. Lane how he figures out that the Calumet earthquake was two degrees less than the San Francisco?

DR. LANE: The scale is one of marks used by the Japanese experts, and the first degree begins with the finest tremors, barely visible on their machine, and so on. Anyhow that is the degrees I referred to published in the California report.

DR. GEO. A. KOENIG: I only ask the question because I have seen some pictures of the City Hall of San Francisco as it looked after the earthquake, and from the way the buildings were rent, and from the way the large columns were flung about, the force of the earthquake shock must have been great. If such a shock or any one within two degrees of it had occurred at Calumet, none of the 150-ft. chimneys could possibly have escaped complete destruction.

MR. MACNAUGHTON: I will ask Mr. Denton if he has anything further to say on the subject.

MR. DENTON: I would not discuss earthquakes for a moment as far as differing from Dr. Lane is concerned, and I don't know how I can, because I have no definite idea on the subject, but about the confusion of ideas referred to by Mr. Kelly I think they are explained in this way, that last night Dr. Lane in his remarks brought in the subject of earthquakes and in speaking about them mentioned this caving in at the Atlantic. And in that way the Atlantic came into association with the one main earthquake which the district has had, and the one of which the center seems to have been at Calumet. And I have no notion whatever in regard to the cause of the one main earthquake which we have had, and only attempted to describe the effects of the Atlantic small earthquake, the cause of which was certainly very apparent—the falling in of the mine, and I think Mr. Kelly has in mind this one large earthquake which was discussed at the same time that the small ones were. In August, at the time of the occurrence of the one large earthquake which you noticed out at the point, we noticed it at Painesdale, which is some twenty miles from Calumet. At the same time that occurred we noticed a slipping of the rocks was located in various places from the fault as far off as Marquette somewhere, I believe, which is spoken of as the best place where such slips might occur. I think Dr. Lane and Mr. Kelly and some others would be the ones to call for.

MR. COOPER: Mr. President, I would like to ask whether in the various bureaus of this district there is any data as to which direction the possible movement was? Whether there was anything to show as to that?

MR. MACNAUGHTON: My personal experience is that the movement was outward; very intense. I wonder whether the degree of intensity of the earthquake might be suggested by the area over which it was felt? Now I understand that the earthquake in San Francisco was not felt in Oakland right across the bay, while the earthquake at Calumet was felt out as far as Eagle Harbor and Painesdale, and on the east as far as Marquette. Would that have anything to do, Dr. Lane, with the degree of intensity?

DR. LANE: I think, Mr. President, the San Francisco affair was recorded in Japan.

MR. MACNAUGHTON: It was recorded clear around the earth. I am under the impression that our earthquake at Calumet was very plainly recorded in the city of Cleveland, because they had a record indicating the time and place, and I have been written to regarding it, whether it could have been the cause of disturbances in some of the mines here, but I mean that while the psychograph would register it in Japan and right around the earth, for some reason it was not felt in Oakland, I understood from the newspaper account at the time.

A MEMBER: Do you mean the extent of the earthquake in San Francisco, that it did not reach Oakland?

ATLANTIC MINE.
No. 3.—Switch Stand Shown on Right Edge of Plate 2. Shows Turning of Ties Caused by Movement of Rails.

ATLANTIC MINE.
N. 2.—Effect of Compression on Track Nearly Over Outcrop of Lode. Parallel Track Shown in Plate 1, and Southwesterly From It.

ATLANTIC MINE.
No. 4.—Looking Northeast Along Direction of Strike, Showing Caved Ground at Surface.

LAC LA BELLE, Now the Terminal of Keweenaw Central Railroad, Showing Three-Head Stamp Mill Built Twenty Years Ago and Used Only a Few Months; Also Smelter Building in Which Furnaces Were Never Installed.

(Photo by Nara, Calumet.)

ATLANTIC MINE.

No. 1.—Effect of Compression on Track Nearly Over Outcrop of Lode, Looking Southeasterly.

CHAMPION MINE QUADRUPLE EXPANSION COMPRESSOR.
Regenerative Feed Water Heating System.

MR. MACNAUGHTON: So far as any impression they got aside from the sensitive instrument. I don't really know what distance Oakland is from San Francisco, but it is comparatively close.

MR. KELLY: I think the falling of chimneys at Oakland was chronicled.

MR. MACNAUGHTON: I understand that was not the particular time of the disturbance in San Francisco.

MR. POPE: The Del Monte Hotel was 100 miles south of San Francisco and several chimneys fell there, and at Salinas some railroad tracks were moved five or six feet, and at Shoshone the tracks went down six feet, and a number of towns north of San Francisco were destroyed. The damage was spread over an area of 125 miles. I think it worth while to call attention to the fact that the jar of an earthquake, like the jar of a gunpowder explosion in the air, is liable to be reflected in spots. It will not be so intense in certain regions as it will in others.

DR. LANE: I heard Dr. Branner lecture on the San Francisco earthquake, which was intense along a north and south line, but Oakland was relatively protected. Now in regard to Mr. Cooper's question about the direction of the earthquake, there is a certain amount of information as to the direction of these shocks, but whether they are man-made or whether they are otherwise made, it is not very definite or very satisfactory.

MR. HEARDING: I will state that I read recently in the National Geographical Society, a publication in which they show a map of the peninsula on which San Francisco is situated, and it seems to me, judging from that, that the slip of land occurred to the south of San Francisco, and that this slip or fault, whatever it was in the earth, did not extend across the bay, but the strike of it was in an even direction from Oakland, and it would seem that the effect of the earthquake would not be felt as heavily in Oakland as it would be in the territory adjacent, south of San Francisco. I judge that from looking at the map.

Dr. Hubbard: Speaking of earthquakes in general up here, there need be no particular surprise expressed that we should have genuine earthquakes. The Keweenaw series, by some geologists, is supposed to have been laid down horizontally. While I cannot go quite so far as that, I do believe that the beds of that series may have been laid down at a slight angle, and then tilted by contraction of the earth's surface, so that now we see them dipping towards Lake Superior on this side and to the south on the other side of the lake. Now the tilting of these formations must have been followed by a want of equilibrium. And further our geological studies show that there are a great many shearing or sliding planes in different parts of the series. The best known of these is what is called the slide under the greenstone. Next to that bed we find in places a heavy bed of conglomerate. At a point a little south of the Phœnix that conglomerate disappears and is replaced by a bed of more or less soft material, which the early miners call "the slide." That term has been used in geological descriptions later and applied to other shearing planes noticed in our mines. The shearing may have occurred between two beds along a plane of weakness, or the plane of weakness may have been through one or several beds not parallel with the strike and dip.

Now Irving, in his discussion with Dr. Wadsworth, on the so-called contact fault at the junction of the eastern sandstone and the Keweenaw series, said that a certain hypothesis advanced by Dr. Wadsworth called for an extraordinary elevation of the Keweenawan and a subsequent erosion of those beds that could not well be explained. But if we take into consideration the phenomena at the Central mine—the faulting of the fissure vein (which runs north seven degrees west) from its supposed continuation below the Kearsarge conglomerate, we see that there may have been a movement of at least three miles of the beds above the conglomerate down over the beds underneath. That is the best example of shearing we have thus far noticed in the Keweenaw series on Keweenaw Point. I might mention a dozen others, but that example without the others shows conclusively that we have had earth movements in this region on a very large scale during past geological ages, and it is not unreasonable to infer that those movements may have been accompanied by earthquakes.

I might add, that in addition to all the so-called slide faults that I have mentioned, there is, at or near the contact of the Eastern Sandstone and the Keweenaw series, a general fault which I do not think follows along the plane or dip of the series. I cannot agree with some of the other geologists that the fault lies altogether between the two formations. I think that it runs down into the Keweenaw series. That is probably one of the most extensive faults we know of in this region.

Now as to the Atlantic phenomena, I went out to the Atlantic mine with Dr. Lane and took photographs. I was not present last night and do not know what facts were stated, but the twisting of the rails there showed, according to Dr. Lane's notes, an apparent compression of about six feet manifested within the length of two rails, or sixty feet. Now it has been stated that there are no indications on the surface to counterbalance that compression, but on thinking it all over it seems to me that several of the cracks we saw up there were two and a half or three inches wide. Could there not have been many other cracks in the rock surface that would not show in the overlying soil? It would not take a great many more cracks than were visible on the surface to make up the six feet.

MR. SPERR: Mr. President, I am of the opinion that the folding force mentioned by Dr. Hubbard is still in action. Its effect, however, may not always be positive on account of the sinuosities of the upturned strata of the district.

At the Atlantic mine it appears that the footwall was not disturbed, but that there was simply a movement of the hanging wall due to the crushing of the pillars in the mine. At the Quincy mine, on the other hand, there was little movement of the hanging wall, but a considerable disturbance of the footwall. And the footwall vibrations or earthquakes were scarcely transmitted to the hanging wall at all.

It has long been observed that extensive rock strata are under stress, either in tension or compression. The phenomenon is not peculiar to this district. When the rocks yield to the stress to which they are subjected, they vibrate like bars of steel, and the earth quakes.

I certainly think we may have earthquakes in this district, which are due to perfectly natural causes; but I do not think that such earthquakes are at all likely to cause trouble in the mines. The troubles in the mines are man-made and subject to the control of man. If there are to be no crushed pillars and air-blasts, there must be no pillars left standing. I do not mean to say that pillars should not be made use of, but that they should be removed as early as possible. Shaft pillars may be maintained for a long time if the stopes between the pillars are large enough to allow the hanging wall to break and relieve the weight upon the pillars. Drift pillars and stope pillars left standing have a tendency to cause a horizontal thrust or a creep of the hanging wall; and when this creep is once started, the shaft pillars are not able to withstand it. The grinding action is liable to continue for a long time unless a sufficient number of pillars can be removed to allow the hanging wall to break and come down upon the foot. It is undoubtedly better to avoid the use of shaft pillars altogether where it is possible to do so.

MR. McNAIR: It seems that this is a case where one man's word is pretty nearly as good as another's. We may say this, that possibly those who do not live in this district may have gotten the idea that when these underground disturbances happen something tremendous occurs in the mine, and things are pretty badly smashed up. That is quite far from true, and it is surprising how much disturbance can take place on the surface and not be felt in the mine. I happened, some two years ago to be in the Quincy mine when one of these local disturbances which we call air-blasts occurred. I was on the level below and about 150 feet to one side of the pillar, a part of which crushed off. There was really no disturbance at all to speak of where I happened to be. There were two sounds there very much like muffled blasts and some rock came tumbling down, and once nearby, but no one was hurt and the top of the mine was wholly undisturbed, and some of the men in the mine knew nothing of what had occurred, as nothing was said on coming out. That disturbance casued a vibration which was felt quite distinct in Hancock and across on the Houghton side.

It was felt out as far as the College of Mines, and it was very hard to realize that such a thing occurred, because so little was the disturbance underground.

MR. MACNAUGHTON: If there is no further discussion on the subject of earthquakes, the secretary will read the report of the council meeting.

## REPORT OF THE COUNCIL.

**Secretary's Report of Receipts and Expenditures from October 17th, 1905, to August 8th, 1906.**

| | | | |
|---|---|---|---|
| **Receipts—** | | | |
| **Balance on hand October 17th, 1905** | | | **$3,638.97** |
| **Received for dues, 1905** | | **$2,015.00** | |
| **Received for back dues** | | **195.00** | |
| **Received for dues, 1906** | | **35.00** | |
| **Received for sale of proceedings** | | **49.01** | |
| **Received for interest on deposits (10 months)** | | **101.59** | |
| **Total receipts** | | | **2,395.60** |
| **Grand total** | | | **$6,034.57** |
| **Disbursements—** | | | |
| **Stationery and printing** | **$ 36.58** | | |
| **Postage** | **107.00** | | |
| **Freight and express** | **17.22** | | |
| **Telephones and telegraphing** | **9.36** | | |
| **Secretary's salary** | **500.00** | | |
| **Clerical work and stenography** | **59.33** | | |
| **Total** | | **$729.49** | |
| **Publishing Proceedings, Volume XI—** | | | |
| **Printing and binding** | **$549.50** | | |
| **Lithographing** | **111.06** | | |
| **Photos, maps and cuts** | **73.40** | | |
| **Total** | | **733.96** | |
| **Expense of last meeting, badges, stenography, etc.** | | **175.00** | |
| **Total disbursements** | | | **$1,638.45** |
| **Cash on hand** | | | **4,396.12** |
| **Grand total** | | | **$6,034.57** |

| Membership— | 1905 | 1906 |
|---|---|---|
| Members in good standing | 371 | 410 |
| Honorary members | 3 | 4 |
| Life members | 1 | 1 |
| Members in arrears | 57 | 50 |
| Total | 432 | 465 |
| New members admitted | 97 | 64 |
| Members not qualified | 9 | 7 |
| New members added | 88 | 57 |

A. J. YUNGBLUTH,
Secretary.

## TREASURER'S REPORT.

Report of the Treasurer of The Lake Superior Mining Institute, showing receipts and disbursements, from October 18th, 1905, to August 7th, 1906, as follows:

| | | |
|---|---|---|
| Cash on hand October 18th, 1905 | $3,638.97 | |
| Received from the secretary | 2,294.01 | |
| Interest on deposits | 101.59 | |
| Paid drafts issued by the secretary | | $1,638.45 |
| Balance on hand August 7th, 1906 | | 4,396.12 |
| | $6,034.57 | $6,034.57 |

E. W. HOPKINS,
Treasurer.

August 9th, 1906.

The undersigned committee appointed to audit the books of the Secretary and Treasurer, beg leave to report that they have carefully examined the same, and find them to be in accordance with the above statements.

CHAS. E. LAWRENCE,
D. T. MORGAN,
CHAS. C. JONES,
Auditing Committee.

The following applications for membership are approved by the Council:

Baldwin, C. Kemble, Chief Engineer, Robins Conveying Belt Co., 749 Railway Exchange Bldg., Chicago, Ills.

Bandler, Arthur S., Diamond Merchant, 65 Nausau St., New York City.

Belden, William P., Solicitor, Ishpeming, Mich.

Birckhead, Lennox, General Sales Agent, The Bucyrus Co., Milwaukee, Wis.

Blackwell, Frank, Mining Engineer, Ironwood, Mich.

Bloomfield, Walter, Supply Clerk, Quincy Mine, Hancock, Mich.

Bonnell, Everett S., Assistant Master Mechanic, Ishpeming, Mich.

Brigham, Edmund D., Jr., Mining, Colorado School of Mines, Hartsel, Colo.

Castle, W. B., Manager, J. Pickands & Co., Marquette, Mich.

Charlton, William Hurst, Clerk, Winona Copper Co., Houghton, Mich.

Clark, Kimball, Manager of Kimball & Clark Lbr., Hurley, Wis.

Cokefair, Frank A., Electrical Engineering, Providence Bldg., Duluth, Minn.

Cummings, P. H., Mining Engineer, C.-C. I. Co., Ishpeming, Mich.

Douglas, Robert Arthur, Publisher News-Record, Ironwood, Mich.

Dunstan, Robert P., Mining Engineer, Hancock, Mich.

Eaton, Lucien, Superintendent, Iron Belt Mine, Iron Belt, Wis.

Erickson, Carl E., Hardware Merchant, Ironwood, Mich.

Fackenthal, B. F., Jr., President, Thomas Iron Co., Easton, Pa.

Goodale, G. S., Mining Engineer, Calumet, Mich.

Grierson, Edward S., Chief Mining Engineer, Calumet & Hecla Mine, Calumet, Mich.

Holly, Carlos E., Mechanical Engineer, Bessemer, Mich.

Holman, J. Winchester, Secretary and Treasurer, The Mining World Co., 1420 Monadnock Bldg., Chicago, Ills.

Holtenhoff, A .V. B., M. M., Wolverine Copper Mining Co., Kearsarge, P. O., Mich.

Hunter, Roy D., General Sales Manager, Sullivan Machinery Co., Railway Exchange Bldg., Chicago, Ills.

Johns, Alexander S., Mining Superintendent, Wakefield, Mich.

Jolly, John, Underground Superintendent, Painesdale, Mich.

Kearney, F. H., Merchant, Ironwood, Mich.

Knight, William H., Mining Captain, Bessemer, Mich.

Koepel, Ed., Mill Superintendent, Beacon Hill, Mich.

Ladd, David H., Assistant Superintendent, Michigan Smelting Works, Houghton, Mich.

Lawton, Charles H., Superintendent, Quincy Mine, Hancock, Mich.

Lien, Nels, Mining Captain, Eveleth, Minn.

Lytle, Alexander James, Electrician, Superintendent, Norway Lighting Plant, Norway, Mich.

Menche, A. H., Assistant, Geological Survey of Michigan, Houghton, Mich.

McIndoe, James A., D. D. S., Norway, Mich.

McGonagle, William A., Vice President, D. M. & N. Ry. Co., Wolvin Bldg., Duluth, Minn.

Mowatt, Neville P., Salesman, Garlock Packing Co., 72 So. Canal St., Chicago, Ills.

Nicholas, Thomas J., Mining Captain, Sparta, Minn.

Nixon, John Allison, Diamond Drill Superintendent, Ishpeming, Mich.

Orbison, Thomas W., Hydraulic Engineer, Appleton, Wis.

Phillips, W. G., Salesman, Calumet, Mich.

Powell, D. W., Contractor, Marquette, Mich.

Presho, Edward W., Mining Stocks, Houghton, Mich.

Quigley, G. J., Superintendent, C. & N. W. Ry., Kaukauna, Wis.

Reider, J. T., Chief Clerk and Purchasing Agent, Houghton, Mich.

Richey, E. W., General Sales Agent, Standard Forgings Co., 1617 Railway Exchange Bldg., Chicago, Ills.

Ridley, Edward William, Mining Engineer, Calumet & Hecla, Calumet, Mich.

Rashliegh, William John, Superintendent, Armenia Mine, Crystal Falls, Mich.

Rowe, Henry, Assistant Superintendent, Oliver Iron Mining Co., Ironwood, Mich.

Ruez, George F., Stock Broker, Ishpeming, Mich.

Schubert, George P., Instructor, Michigan College of Mines, 211 Vivian St., Hancock, Mich.

Shea, J. D., Mining Captain, Bessemer, Mich.

Stevens, Max., Merchant, Ironwood, Mich.

Sullivan, T. J., Chief Clerk, Oliver Iron Mining Co., Ironwood, Mich.

Swift, H. Leigh, Mining Supplies, Houghton, Mich.

Walker, Elton W., Superintendent, Tombstone Consolidated Mine, Tombstone, Arizona.

Wallace George, Agent, Dupont Powder Co., Marquette, Mich.

Watson, Charles H., Lawyer, Crystal Falls, Mich.

Williams, Thomas H., Mining Captain, Ely, Minn.

Williams, Herbert H., President, Lake Shore Engine Works, Marquette, Mich.

The Council recommends that the salary of the secretary for the ensuing year be seven hundred and fifty dollars.

On motion the report of the Council was adopted and the secretary instructed to cast a ballot for the election of the applicants to membership in the Institute.

The auditing committee presented the report on the examination of the accounts of the secretary and treasurer, which report was on motion adopted.

Mr. George A. Newett presented the following resolution:

Resolved, That a vote of thanks be tendered to the committee on arrangement, transportation and entertainment, also to the railroads and mine managements and citizens generally of the copper country who have contributed to the pleasure and success of this, the twelfth annual meeting of the Lake Superior Mining Institute.

The resolution was adopted by the unanimous vote of the meeting.

The committee on nominations presented the following report:

Your committee on nominations beg leave to submit the following names as officers of the Institute for the term specified:

For President: (one year) Thomas F. Cole, of Duluth, Minn.

For Vice-Presidents: (two years) David T. Morgan, of Republic, Mich.; D. E. Sutherland, of Ironwood, Mich.; Norman W. Haire, of Hancock, Mich.

For Managers: (two years) J. Ward Amberg, of Chicago, Ills.; Pentacost Mitchell, of Duluth, Minn.

For Manager: (one year) John C. Greenway, of Bovey, Minn.

For Secretary: (one year) A. J. Yungbluth, of Ishpeming, Mich.

For Treasurer: (one year) E. W. Hopkins, of Commonwealth, Wis.

WILLIAM KELLY,
GEO. A. NEWETT,
GEO. D. SWIFT,
GEO. H. ABEEL,
F. W. DENTON,
Committee.

The report of the committee was on motion adopted and the secretary instructed to cast a ballot for the election of the officers presented by the committee.

Mr. Hearding: Mr. President, I wish to suggest that in the proceedings of this year the names of the old pioneers of this region be inscribed, with a short history or reference to their connection with the mines of this region, and a brief note as to their length of life here, or the time of their death. I would also suggest that a committee be appointed for the purpose of elaborating and obtaining this data, and it seems to me that if the members of the Lake Superior Mining Institute would only take a little time, those of you who know of men who have been connected with the mining industry in the northern peninsula of Michigan, and the Lake Superior region, they could send in from time to time to such committee or to the secretary of the Institute, or whatever way it may be advisable, these names which could be placed upon our proceedings this year, and that in doing so we would confer a very fitting tribute to the names of those gentlemen who were interested and who have been engaged in the work which we are now carrying out.

Mr. Pope: I think such a suggestion is very proper and I would like very much to see it carried out, and I think if some of the members of our Institute who have had knowledge of these older men who have passed away would furnish a brief notice of them, it could be published in our transactions, and I trust some of these gentlemen will make contributions of this character. It perhaps could not be a complete list, and yet so far as it goes it would be a proper and fitting thing.

With the view of getting the members interested in the matter suggested by Mr. Hearding, the secretary will be pleased to receive any suggestions, also the names of persons who have been prominent in the upbuilding of our mining country and to whom a just tribute could be paid by this Institute. We should make this a special feature of our next publication, which can be done readily if the members will contribute the information necessary.

After announcing the program for the next day's trip, the meeting was on motion adjourned.

The following is a list of members and guests in attendance at the meeting:

ABEEL, GEORGE H....................................Hurley, Wis.
ABEEL, O. J.,.....................Iron Trade Review, Cleveland, O.
ADAMS, J. B.........................................Duluth, Minn.

AMBERG, J. WARD....................................Chicago, Ills.
ANDERSON, G. A....................................Negaunee, Mich.
ARMSTRONG, F. H....................................Vulcan, Mich.

BACON, S. T....................................Ishpeming, Mich.
BAER, HENRY L....................................Hancock, Mich.
BALDWIN, C. KEMBLE....................................Chicago, Ills.
BALLARD, CHARLES ....................................Alliance, O.
BARBER, G. S....................................Bessemer, Mich.
BARBER, MAX L....................................Ironwood, Mich.
BARR, JAMES A....................................Escanaba, Mich.
BAUDER, W. R....................................Ishpeming, Mich.
BAWDEN, T. J....................................Houghton, Mich.
BAXTER, C. H....................................Houghton, Mich.
BELDEN, WM. P....................................Ishpeming, Mich.
BEYENKA, THOMAS ....................................Houghton, Mich.
BIRCKHEAD, LENNOX ....................................Milwaukee, Wis.
BLACKWELL, FRANK ....................................Ironwood, Mich.
BLOOMFIELD, WALTER ....................................Hancock, Mich.
BONNELL, E. S....................................Ishpeming, Mich.
BOONE, C. G....................................Ishpeming, Mich.
BOWMAN, W. P....................................Cleveland, O.
BRANDT, H. M....................................Hancock, Mich.
BRETT, HENRY ....................................Calumet, Mich.
BRIGHT, HARRY....................................Houghton, Mich.
BRIGHAM, E. D., JR....................................Chicago, Ills.
BROUGHTON, H. P....................................Duluth, Minn.
BROWNE, EDWARD D....................................Chicago, Ills.
BURR, FLOYD, L....................................Iron Mountain, Mich.

CAIRNS, F. I....................................Houghton, Mich.
CARNAHAN, ARTHUR L....................................Houghton, Mich.
CARBIS, FRANK....................................Iron Mountain, Mich.
CARPENTER, G. V....................................Iron Mountain, Mich.
CARSON, JOHN A....................................Appleton, Wis.
CASTLE, W. B....................................Marquette, Mich.
CHAMBERS, H. P....................................Florence, Wis.
CHAMPION, CHARLES ....................................Beacon, Mich.
CHARLTON, W. H....................................Houghton, Mich.
CHENEY, V. D....................................Milwaukee, Wis.
CHINN, W. P....................................McKinley, Minn.
CHRISTY, G. P....................................Houghton, Mich.
CHYNOWETH, JAMES ....................................Calumet, Mich.
CLANCEY, THOMAS ....................................Ishpeming, Mich.
CLARK, KIMBALL ....................................Hurley, Wis.
CLARK, H. S....................................Chicago, Ills.
CLEMENS, JOHN....................................Ironwood, Mich.

COAD, RICHARD ......................................Ely, Minn.
COLE, WILLIAM T..................................Ishpeming, Mich.
COLE, CHARLES D..................................Ishpeming, Mich.
COLE, WILLIAM A...................................Ironwood, Mich.
CONLEY, W..........................................Ironwood, Mich.
CONOVER, A. B........................................Chicago, Ills.
COOK, LEO P............Marquette Mining Journal, Houghton, Mich.
COOPER, S. S........................................Ironwood, Mich.
COOPER, JAMES B....................................Hubbell, Mich.
COOPER, C. H........................................Hubbell, Mich.
COPELAND, FRANK ....................................Vulcan, Mich.
CORBETT, J. T........................................Chicago, Ills.
CORNISH, J. H.......................................Negaunee, Mich.
CRAGO, W. H.......................................Iron River, Mich.
CRAPO, C. M.......................................Burlington, Iowa.
COVENTRY, F. L......................................Hibbing, Minn.
COYGEN, T. A........................................Houghton, Mich.
CUNDY, H. J...................................Iron Mountain, Mich.

DANGLADE, E...................................Iron Mountain, Mich.
DAVENPORT, P. E.......................................Duluth, Minn.
DAVIDSON, O. C................................Iron Mountain, Mich.
DAVIDSON, WARD F..............................Iron Mountain, Mich.
DEE, J. R...........................................Houghton, Mich.
DEMMERT, HENRY..............................New York City, N. Y.
DENTON, F. W......................................Painesdale, Mich.
DICKENSON, B.........................................Chicago, Ills.
DOUGLASS, E. F..........................................Mass, Mich.
DOUGLASS, ROBERT A.................................Ironwood, Mich.
DOUGLASS, R. H......................................Houghton, Mich.

EATON, LUCIEN.......................................Iron Belt, Wis.
EDWARDS, A. D...................................Atlantic Mine, Mich.
ELLARD, H. F........................................Ironwood, Mich.
ERICSON, C. E.......................................Ironwood, Mich.

FAIRBAIRN, CHARLES T..................................Duluth, Minn.
FAVOR, GEORGE W......................................Duluth, Minn.
FESING, H. W........................................Houghton, Mich.
FINNEGAN, J. T.......................................Hancock, Mich.
FISHER, JAMES, JR....................................Houghton, Mich.
FITZSIMMONS, U. J....................................Hancock, Mich.
FLODIN, NELS P.....................................Marquette, Mich.
FOX, ARTHUR C.......................................Houghton, Mich.
FOX, JOHN M........................................Ishpeming, Mich.
FRASER, WILLIAM ...............................Crystal Falls, Mich.

GARNER, W. A. ......................................Negaunee, Mich.

GEDNEY, R. E.......................................Chicago, Ills.
GETCHELL, MORTON C.............................Hancock, Mich.
GIBSON, J. T.........................................Amasa, Mich.
GILCHRIST, W. B...................................Cleveland, O.
GILLALAND, W. M................................Hancock, Mich.
GODFREY, M. H....................................Hibbing, Minn.
GOW, A. M..............................................Duluth, Minn.
GRAFF, W. W......................................Ishpeming, Mich.
GRANT, B. F.......................................Wakefield, Minn.
GREEN, W. E. ........................................Cleveland, O.
GRIBBLE, S. J......................................Ironwood, Mich

HAIRE, NORMAN W.............................Houghton, Mich.
HALLER, FRANK.....................................Calumet, Mich.
HALL, C. H. ..........................................Evanston, Ills.
HALL, C. G..........................................Houghton, Mich.
HAMPTON, C. T..............................Iron Mountain, Mich.
HANCHETTE, C. D................................Hancock, Mich.
HARDENBURG, L. M.................................Hurley, Wis.
HARTNERS, J. V. N...............................Houghton, Mich.
HARRIS, J. L..........................................Hancock, Mich.
HARRIS, H. R......................................Marquette, Mich.
HARRIS, S. B.........................................Hancock, Mich.
HARRIS, S. T.......................................Houghton, Mich.
HARRY, WILLIAM......................................Detroit, Mich.
HARVEY, W. H..........................................Eveleth, Minn.
HASTINGS, E. X....................................Milwaukee, Wis.
HEARLEY, MICHAEL T...........................Cleveland, O.
HEATH, G. L..............................................Hubbell, Mich.
HEDIN, A. G..........................................Ironwood, Mich.
HITCHENS, J. H.............................Iron Mountain, Mich.
HICKOK, E. E. ........................................Chicago, Ills.
HOOPER, W. H...................................Ishpeming, Mich.
HOPKINS, E. W. ............................Commonwealth, Wis.
HOPPER, B. D...............................Iron Mountain, Mich.
HODGE, J. E. ......................................Marquette, Mich.
HOLMAN, J. WINCHESTER............Mining World, Chicago, Ills.
HOOD, O. P..........................................Houghton, Mich.
HOUSTON, H. H......................................Chester, Pa.
HOWE, GEORGE D...............................Ironwood, Mich.
HUMPHREY, CHARLES M.....................Ironwood, Mich.
HUNTER, ROY D.....................................Chicago, Ills.

JACKA, J. H.....................................Crystal Falls, Mich.
JACKSON, G. R....................................Princeton, Mich.
JACKSON, J. F.....................................Houghton, Mich.
JANSEN, F. A.............................................Norway, Mich.

JETTNER, A. R....................................Chicago, Ills.
JOHNS, A. S....................................Wakefield, Mich.
JOHNSTONE, O. W....................................Ironwood, Mich.
JOLLY, JOHN....................................Champion, Mich.
JONES, CHARLES C....................................Wakefield, Mich.
JONES, A. G....................................Negaunee, Mich.

KARKEET, J. H....................................Iron Mountain, Mich.
KEITH, J. M....................................Ishpeming, Mich.
KELLY, WILLIAM....................................Vulcan, Mich.
KING, ROBERT....................................Hurley, Wis.
KNIGHT, W. H....................................Bessemer, Mich.
KOENIG, DR. and SON....................................Houghton, Mich.
KRUSE, JOHN C....................................Iron Mountain, Mich.

LADD, DAVID H....................................Houghton, Mich.
LAMB, J. W....................................Winnipeg, Manitoba.
LAMBRIX M....................................Hurley, Wis.
LANG, S. S....................................Houghton, Mich.
LA RUE, HARRY....................................Chicago, Ills.
LAWRENCE, CHARLES E....................................Amasa, Mich.
LAWTON, CHARLES L....................................Hancock, Mich.
LEE, G. M....................................Horricon, Wis.
LETZ, JOHN F....................................Milwaukee, Wis.
LINSLEY, W. B....................................Escanaba, Mich.
LOOK, W. F....................................Escanaba, Mich.
LYNCH, THOMAS F....................................Houghton, Mich.
LYTLE, A. J....................................Norway, Mich.

MAAS, GEORGE J....................................Negaunee, Mich.
MACE, H. A....................................Duluth, Minn.
MACE, HOWARD ....................................Ironwood, Mich.
MACE, ROBERT E....................................Duluth, Minn.
MAYNARD, C. F....................................Milwaukee,. Wis.
METHERAL, SAMUEL ....................................Ishpeming, Mich.
MENCHE, A. H. ....................................Houghton, Mich.
M'CLURE, O. D....................................Ishpeming, Mich.
M'CURDY, W. A....................................Ely, Minn.
McDONALD, D. B....................................Virginia, Minn.
McDOWELL, HANSEN ....................................Houghton, Mich.
M'GEE, M. B....................................Crystal Falls, Mich.
M'GONAGLE, W. A. ....................................Duluth, Minn.
M'GRATH, W. H....................................Houghton, Mich.
McINDOE, JAMES A....................................Norway, Mich.
MILLER, L. B....................................Cleveland, O.
MITCHELL, PENTECOST....................................Duluth, Minn.
MITCHELL, R. J. ....................................Chisholm, Minn.

MITCHELL, W. A. .......... Chicago, Ills.
MORGAN, DAVID T. .......... Republic, Mich.
MOWATT, NEVILLE P. .......... Chicago, Ills.

NANKERVIS, J. L. .......... Calumet, Mich.
NELSON, S. T. .......... Chicago, Ills.
NEWETT, GEORGE A. .......... Ishpeming, Mich.
NIXON, J. A. .......... Ishpeming, Mich.

ORR, FRANK D. .......... Duluth, Minn.
ORRISON, J. .......... Houghton, Mich.
ORRISON, T. W. .......... Appleton, Wis.

PASCOE, J. F. .......... Vulcan, Mich.
PASCOE, P. W. .......... Republic, Mich.
PASCOE, T. J. .......... Norway, Mich.
PERKINS, SAMUEL J. .......... Ironwnod, Mich.
PETERSON, J. O. .......... Hancock, Mich.
PHILLIPS, W. G. .......... Calumet, Mich.
POPE, GRAHAM .......... Houghton, Mich.
PRESTO, EDWIN W. .......... Houghton, Mich.

QUIGLEY, G. J. .......... Kaukauna, Wis.
QUINE, JOHN T. .......... Ishpeming, Mich.

REEDER, J. T. .......... Calumet, Mich.
REIGART, J. R. .......... Ishpeming, Mich.
RICE, J. H. .......... Houghton, Mich.
RICHARDS, W. J. .......... Houghton, Mich.
RICHEY, E. W. .......... Chicago, Ills.
ROBERTS, EDWARD .......... Iron River, Mich.
ROBERTS, HARRY .......... Duluth, Minn.
ROBERTS, RICHARD .......... Negaunee, Mich.
ROBERTSON, JAMES .......... Marquette, Mich.
ROGE, COL. G. E. .......... New York City, N. Y.
ROSE, R. S. .......... Marquette, Mich.
ROUGH, J. H. .......... Negaunee, Mich.
ROWE, HENRY .......... Ironwood, Mich.
ROWE, JAMES .......... Iron Belt, Wis.
ROWELL, THOMAS .......... Iron Mountain, Mich.
RUEZ, GEORGE F. .......... Ishpeming, Mich.
RUNDELL, A. J. .......... Iron Mountain, Mich.

SAMPSON, JOHN .......... Ashland, Wis.
SCHNATTERBECK, C. C. DR. .......... Mining World, Chicago, Ills.
SCHWARTZ, J. E. .......... Houghton, Mich.
SELLS, MAX .......... Florence, Wis.

SENTER, A. W. .......................................... Hubbell, Mich.
SHEA, J. D. .......................................... Bessemer, Mich.
SHELDEN, R. SKIFF .......................................... Houghton, Mich.
SHERLOCK, THOMAS .......................................... Escanaba, Mich.
SHIELDS, IRWING J. .......................................... Hancock, Mich.
SIEBENTHAL, W. A. .......................................... Republic, Mich.
SILLIMAN, A. P. .......................................... Hibbing, Minn.
SKINNER, M. B. .......................................... Chicago, Ills.
SMETHERAM, EDWIN .......................................... Houghton, Mich.
SMITH, S. R. .......................................... Calumet, Mich.
SMITH, T. W. .......................................... Hancock, Mich.
SMITH, WILL P. .......................................... Hancock, Mich.
SOADY, HARRY .......................................... Iron Mountain, Mich.
SPEAR, JOHN H. .......................................... Ironwood, Mich.
SPENCER, J. T. .......................................... Iron Mountain, Mich.
SPERR, F. W. .......................................... Houghton, Mich.
SPORLEY, C. L. .......................................... Negaunee, Mich.
STANLAKE, JAMES .......................................... Ironwood, Mich.
STAPLES, NELSON .......................................... Victoria, B. C.
STEEL, J. .......................................... Milwaukee, Wis.
STEVENS, MAX .......................................... Ironwood, Mich.
STEVENS, THOMAS J. .......................................... Ironwood, Mich.
STEWART, H. E. .......................................... Houghton, Mich.
STOEK, H. H. .......................................... Mines & Minerals, Scranton, Pa.
STURTEVANT, H. B. .......................................... Tucson, Ariz.
SULLIVAN, F. J. .......................................... Ironwood, Mich.
SUNDERLAND, J. E. .......................................... Calumet, Mich.
SWAIN, R. A. .......................................... Duluth, Minn.
SWIFT, GEORGE D. .......................................... Duluth, Minn.
SWIFT, H. L. .......................................... Houghton, Mich.
SWIFT, PAUL D. .......................................... Houghton, Mich.

TOLAN, WILLIAM .......................................... Ironwood, Mich.
THOMPSON, C. M. .......................................... Marquette, Mich.
TREBILCOCK, JOHN .......................................... Ishpeming, Mich.
TRIPP, CHESTER D. .......................................... Chicago, Ills.
TRUSCOTT, HENRY .......................................... Loretto, Mich.
TURNER, JOHN .......................................... Milwaukee, Wis.

UREN, W. J. .......................................... Calumet, Mich.

VAN ORDEN, F. L. .......................................... Houghton, Mich.
VAN VALKENBURG, A. J. .......................................... Abbotsford, Wis.
VAUGHN, S. H. .......................................... Milwaukee, Wis.

WADE, C. E. .......................................... Philadelphia, Pa.
WALKER, W. E. .......................................... Tombstone, Ariz.

WAGNER, JOHN M. .... Houghton, Mich.
WALLACE, GEORGE .... Marquette, Mich.
WALL, J. S. .... Iron Mountain, Mich.
WALSH, ARTHUR .... Chicago, Ills.
WALTON, C. E. .... Wakefield, Mich.
WAPLES, BELMONT .... Ironwood, Mich.
WARE, J. F. .... Dayton, O.
WEBB, CHARLES E. .... Houghton, Mich.
WEBER, R. G. .... Kansas City, Mo.
WEED, WALKER HARVEY .... Washington, D. C.
WELLS, A. J. .... Cleveland, O.
WHITBURN, HENRY .... Navarre, Mich.
WHITEHEAD, R. G. .... Amasa, Mich.
WHITE, PETER .... Marquette, Mich.
WHITFIELD, T. F. .... Milwaukee, Wis.
WHITNEY, A. E. .... Ishpeming, Mich.
WILLIAMS, H. H. .... Houghton, Mich.
WILLIAMS, JAMES H. .... Ishpeming, Mich.
WILLIAMS, J. P. .... Schullsberg, Wis.
WILLIAMS, Q. H. .... Ely, Minn.
WILLIAMS, THOMAS .... Ironwood, Mich.
WILLIAMS, P. S. JR. .... Bingham, Utah.
WINCHELL, HORACE V. .... Minneapolis, Minn.
WORDEN, JOHN .... Hancock, Mich.

YOUNG, H. OLIN .... Ishpeming, Mich
YOUNGS, GEORGE C. .... Florence, Wis.
YUNGBLUTH, A. J. .... Ishpeming, Mich.

# THE GEOLOGY OF KEWEENAW POINT—A BRIEF DESCRIPTION.

By Alfred C. Lane, State Geologist.

## THE LAKE SUPERIOR BASIN.

The Keweenawan or copper bearing rocks surround the Lake Superior basin. This, which is a real concavity in the earth's crust, is also a geological basin. Accordingly the beds on the northwest of the lake dip to the southeast, and those on the south dip northward. (Fig. 1). The Huronian, the iron-bearing older rocks of the Huron mountains, the country from Marquette to L'Anse, are matched by others in Canada around Port Arthur. Overlapping these there is an inconspicuous fringe of the traps of the copper-bearing series, exposed on the south side from the head of Keweenaw bay past the south end of Lake Gogebic and along the north shore of Lake Superior from Duluth to Nepigon. Then we find that the center of the basin has been crowded out of its place and lifted up. Slow contraction of the earth cooling under it may have sprung it up or it may have been lifted up on the back of some vast intrusion such as the great gabbro which seems to crowd in at the base of this formation in Wisconsin. Thus we find that, after passing over the nearly flat lying sandstones (exposed near the Mass mill) which cover this fringe of Keweenawan in the valley extending from the head of Keweenaw bay, we come to a great fault or crack, on the northwest side of which the rocks are uptilted. This crack runs the length of Keweenaw point from Bete Gris bay past the north end of Lake Gogebic. Against this the copper bearing series is uplifted in

*I owe to Mines and Minerals the blocks of some cuts illustrating this article, prepared by them from rough copy supplied by me.

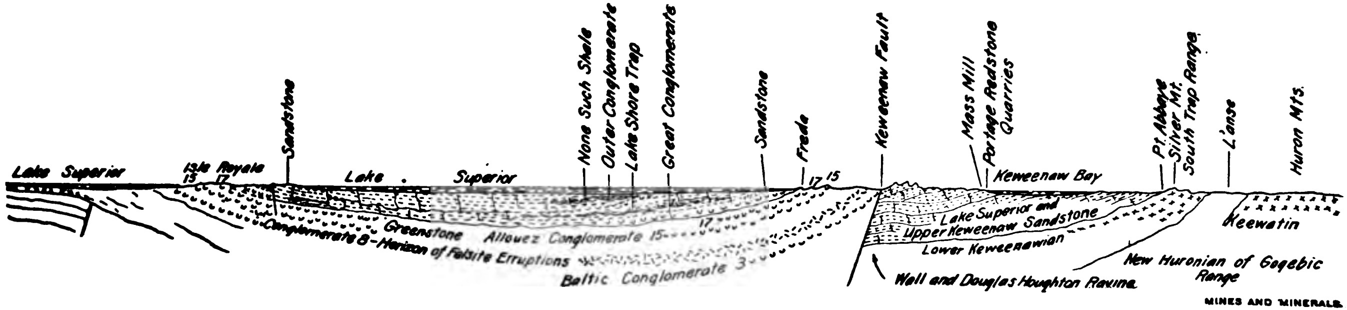


Fig. 1, Cross-Section of Lake Superior.

beds dipping at first steeply, then more gradually northward to the lake. These beds are matched on the other side by Isle Royale, which has steep dips and felsite at its north margin, as Keweenaw point has on its south margin. The back bone of Isle Royale and Keweenaw point is the same lava flow and the former is fringed on the south side by sandstone, while on Keweenaw point sandstones will be seen near the various mill sites at Freda.

### THE KEWEENAW FAULT.

One reason for thinking that the great fault which bounds the copper range on the south is not due to an intrusion, but is due to some long, slow action, like the shrinkage of the earth, is that there seems to have been motion along it for ages. Not so very far from it at Limestone mountain (in Sections 23 and 24, T. 51 N., R. 35 W., and again in Section 7 northeast) Paleozoic strata as late as the Niagara are caught and preserved in a fold in the Lake Superior sandstone, which all along close to the line of the fault is disturbed from its normally nearly horizontal position. A picturesque instance of this is the Wall ravine not far north of Lake Linden, which, as well as the more noted Douglass Houghton ravine and falls, is close to the electric line from Calumet to Lake Linden. A mile or two south of the College of Mines a number of ravines also show the fault, and the same region shows indications of faulting before as well as after the deposition of the Lake Superior sandstone, in the overlap of this sandstone upon the upturned copper range. Fragments of the lower beds of the Keweenawan series are also found in the higher conglomerates of the same formation, showing that the uplift began in Keweenawan time.

### OTHER CRACKING.

With this uplift naturally came a good deal of fracturing of the rocks, which has had its influence on the deposition of copper. The amount of uplift varies in different parts of the range, While around the Calumet mine the beds dip at the surface from 41° to 38°, around Hancock and Houghton the dip is nearer 56° and the mines on the Baltic lode dip nearly 70°. This variation may be connected with many fractures running across the formation. Very often these are mere seams filled with calcite or quartz or laumonite or copper or its ores, chalcocite, or in the Mohawk mine with the arsenide of copper and nickel, Mohawkite. At other times the strata are displaced, but usually only a short distance. A notable instance is the displacement on Section 16, T. 54 N., R. 34 W., south of Houghton, which has hindered the Atlantic so much in developing the Baltic lode.1 Hardly a mine is entirely without them. Usually, but not always, at a northward running fissure the east side is thrown south, or to the right, yet in drifting along a bedded lode across such a fractured belt it may never be lost entirely but simply suddenly deflected from its usual course on entering the belt of disturbed ground or shearing zone. Very commonly a change in its productiveness also appears. Out on the point where the dips are relatively flat the cross fissures were the first and most extensively mined and the bedded zones near them richer. Near Portage lake the reverse seems quite as often true. But fissures across the formation are by no means the only ones. If we bend up a pack of cards we notice a good deal of slipping of one card over the other and unquestionably there has been much slipping of one bed over the other on Keweenaw point. Often the slipping seems to be exactly along the contact of two beds, but in the Ontonagon district for instance faults or fractures, running practically with the beds but dipping more steeply, are well known important factors.2 They may be more important around Portage lake than it is easy to prove.

While the faults and fractures parallel to the strike of the beds are usually called slides, it is not always easy to prove that the upper beds have really gone down, that is to say that they are "normal" faults. However, it is probable and would

1Michigan Geological Survey Vol. I, Part II, Plate X.
2Well described in Van Orden's report on the Michigan mine.

seem natural that when not exactly with the bedding they dip more steeply. In such case they must be normal if, as seems true, they rarely if ever produce repetition of the same bed, but much more often a bed or part of a bed seems stricken from the series. Thus the well known slide under the Greenstone seems to have wiped out of existence the Albany & Boston conglomerate, and a similar slide has in many places reduced the Wolverine sandstone to a mere remnant. The Kearsarge conglomerate appeared at the bottom of the Central mine but was wiped out in the upper levels. (Prac. L. S. Mining Institute, 1895, Pl. 3, etc.) In general if we compare sections in different crosscuts, which often fail to match as one might expect, it seems as if in some of them there were something gone. This is easy to note when a conglomerate is gone, not so easy when a trap is merely reduced in thickness.

## CHARACTER OF THE BEDS.

The copper-bearing rocks are mainly a series of old lava flows. Much the commonest type is the same as a common basalt The amount of silica is about 46%, of alumina 15%, of iron oxides 13%, lime up to 10%, magnesia and soda making together about 10% and not over 1% or 2% each of carbon dioxide, titanic oxide; water and other ingredients make up the balance. An analysis of the typical ophite figured in the plate of my annual report for 1904, by F. K. Ovitz in the laboratory of Prof. E. D. Campbell is

| | |
|---|---|
| Silica, $SiO_2$ | 45.21 |
| Alumina, $Al_2O_3$ | 15.85 |
| $TiO_2$ | 2.14 |
| Ferric oxide, $Fe_2O_3$ | 9.55 |
| Ferrous oxide, FeO | 4.37 |
| Calcium oxide, CaO | 10.36 |
| Magnesium oxide, MgO | 7.25 |
| Manganous oxide, MnO | .89 |
| Sodium oxide, $Na_2O$ | 2.47 |
| Potassium oxide, $K_2O$ | .31 |
| Phosphorus anhydride, $P_2O_5$ | .165 |
| Carbon dioxide | .48 |

| | |
|---|---|
| Sulphur | .07 |
| Chlorine | .04 |
| Moisture | .67 |
| Loss on ignition | 1.36 |
| | 100.985 |

There is a duplication of moisture and carbon dioxide in the loss on ignition. As a slag its formula might be written:

$CaO$, $MgO$, $(Na_2O\ FeO)$ $(FeAl)_2O_3$, $4\ SiO_2$.

This has a striking resemblance to an augite formula.

Rhyolitic siliceous lavas or felsites rarely occur, mainly in the lower part of the series below the horizon of the Arcadian lode and there are intermediate forms. The normal lava appears to be very close in the new chemical classification of rocks to the line between a hessose and an auvergnose. The chief original minerals are feldspar, augite, magnetite and olivine. In an average looking rock there is perhaps 55% of feldspar, 25% to 30% of augite and the balance magnetite, olivine and various minerals ordinarily called secondary.

The top of each flow was naturally more likely to be open in texture, full of bubbles, and thus more porous and easily crushed. Such tops are known as amygdaloids, and they are sought by the explorer, for in the filling of their pores the copper may be concentrated. A real amygdaloid top to an independent lava flow is likely to be fairly persistent and has numerous round walled cavities often filled with some white mineral. Its top is commonly pretty well marked while its base fades out gradually into the underlying not bubbly compact part of the flow which is distinguished as "trap."

But just as modern lavas or streams of slag are liable to gush over and envelope cooled crusts, or crystallize and leave cavities like those lined with melitlite crystals in the pots of slag from the copper cupola furnaces, so was it with these old lavas. Amygdaloidal streams often run down into the trap and amygdaloid spots, bombs, or inclusions, characteristic under the Wolverine sandstone, are often found in the solid trap, and coarsely and openly crystallized "doleritic"* streaks are also found especially in very thick flows, and in the interstices of the crystals calcite, etc., may form giving them also a spotted and amygdaloid appearance.

The trap under the amygdaloid, the foot wall trap, is liable to be relatively lighter and more feldspathic, that being the lighter mineral. The feldspar is generally oligoclase or labradorite, and appears like rice-like grains if the rock is coarse enough. The darker interstitial matter is mainly augite or its alteration product, chlorite. The olivine is easiest recognized when it is more or less changed to a reddish micaceous mineral. The magnetite is not conspicuous in the hand specimen, but is easily attracted from the powder. The hanging wall trap is generally darker and more augitic.

If the rock is quite feldspathic and the feldspar oligoclase there is a strong tendency for the feldspar to crystallize out early, either in sharp crystals or groups, which where somewhat decomposed are quite easily mistaken, especially in the uncertain light of the mine, for the white filled amygdules. Such traps are particularly conspicuous above the "Greenstone" at about the horizon of the Ashbed.

At other times large crystals of labradorite are characteristic of a flow. This is true of the big trap whose amygdaloid top is the Kearsarge amygdaloid. When the flows are very feldspathic or siliceous the grain tends to be fine, the fracture conchoidal, the ring clear. When the flows are quite augitic the feldspar laths are imbedded in the augite and the olivine and magnetite crowded between the augite patches. These increase in size as one goes from the base of the flow toward the center. The increase is not absolutely regular and depends on the composition and other circumstances as well, but pretty commonly the diameter attains .125 inch in less than 10 feet and then increases so that in 400 feet it is about an inch. These rocks Pumpelly very graphically called luster-mottled melaphyres, since a freshly broken piece held in the light shows

*Vol. VI., Part I., Pl. 6, Fig. 3 and p. 167.

lustrous mottlings from the augite cleavage. The fracture is rough and hackly, not smooth, and on a weather beaten surface the augite centers seem more resistant than the interstices and stand out in knobs which give a pockmarked appearance which led the rock to be called in Foster & Whitney's time varioloid greenstone. It finally may break down to an angular gravel, each grain of which has one augite nucleus, a smoothed surface, like that of a beach pebble or diamond drill core, is mottled like an ophidian's (snake's) back and so French writers some time ago called such rocks ophites, a term I myself prefer as short, easy, early, and built like other rock names.

The term ophite may be defined as the name of a rock whose augite will give the luster mottled appearance where it is coarse and fresh enough.

### GENERAL SUCCESSION OF ROCKS.

When we began work on the Black River cross section near Bessemer it was expected that the traps of the South range* coming around from the south end of Lake Gogebic would be a repetition of some part of the main range from Keweenaw point. This does not, however, appear to be true. The traps from Bessemer to North Bessemer appear to be the oldest. While there are many of ordinary character, there are a number of beds with very conspicuous porphyritic feldspar in them. The pipe amygdules at the bottoms of flows are often well marked quartzose and agate amygdules. There are intrusive diabase dikes, and near the Bessemer poor farm a tongue of coarse gabbro, and near the top part of this series not far from the North Bessemer station a genuine feldspar porphyry or felsite, capped by a felsitic breccia.

A somewhat similar series with felsite and gabbro intrusives and coarsely porphyritic beds was again found near the base of the series and carefully described by Dr. Hubbard from

*This used to be the only South range. Of late years it has become customary to allude to the mines just south of Portage lake as the South range, and the town of South Range has been named accordingly.

the Bare Hills and the south slopes of Mount Houghton and Mount Bohemia. The uppermost limit is the Mount Bohemia conglomerate, which can be traced nearly to Calumet with some assurance. But it is not yet quite clear to which of the conglomerates farther south it belongs.

Marvine, who did the most detailed work on the correlation of the lodes that has been done, counted, beginning at the lowest he found, 18 sedimentary beds of various thicknesses intercalated in the series of traps, as they cross Portage lake. (Fig. 2). In a few cases he may have given overlaps of the same bed two numbers, and he may have overlooked a few.

The Mount Bohemia conglomerate may be continuous with conglomerate 3, the Baltic conglomerate, which lies not far beneath the Baltic lode in the mines south of Houghton. It may possibly be continuous with conglomerate 8, but certainly not higher. Conglomerate 8, the Minnesota conglomerate, passes a few hundred feet below the Arcadian, Isle Royale and Winona lodes, which appear to be practically identical, and the 2,600 feet or so of beds between it and conglomerate 3 at Portage lake include in the upper part not less than four well marked felsitic conglomerates, while the traps, especially toward the base, are good heavy ophites a hundred feet thick or so with clinkery amygdaloid tops, which when broken up by sliding are not easy to distinguish from conglomerates made up of amygdaloid fragments.

As we go south from Houghton toward the Winona the top series become thinner, the conglomerates thicker, and in general (though not for individual beds) there is a thinning from Keweenaw point to the southeast, at least as far as the Winona, where the shrinkage from Calumet is nearly 50%.

While faulting may displace or cause uncertainty as to individual outcrops, the general conglomeratic horizon, from 5 to 8 can be quite safely traced from the Arcadian mine to the Ontonagon river (Fig. 3).

There is a great thickness (some 3,000 feet) of traps, very little sandstone and no conglomerate between conglom-

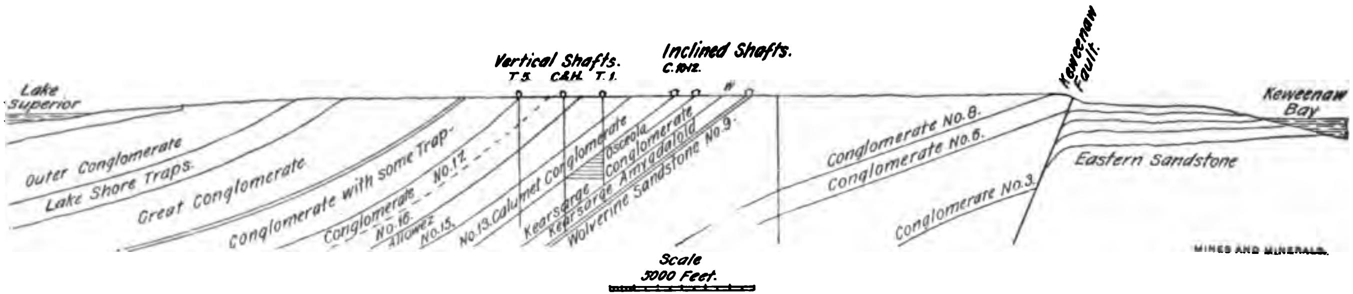


Fig. 2, Cross-Section of the Copper Range Near Calumet.

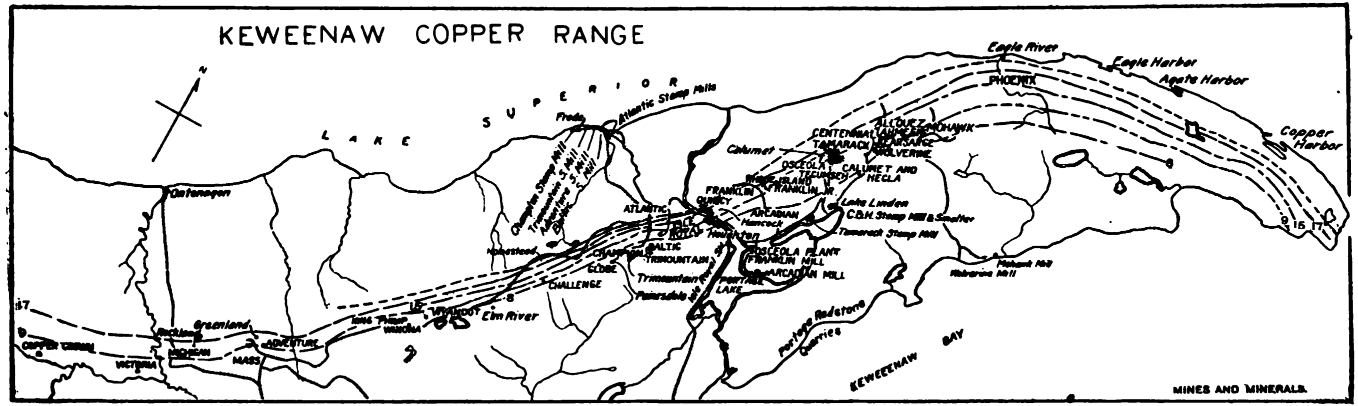


Fig. 3, Outline Map of the Keweenaw Copper Range.

erate 8 and 9.* The traps are usually ophites, though often quite feldspathic and inclusions or bomb-like masses which generally appear extra green and sometimes amygdaloidal are not uncommon.

Bed 9, the Wolverine sandstone, tends to be a sandstone and is sometimes 40 feet or more thick, but as frequently is wiped out almost entirely, though usually on one side or the other of the clay fluccan which marks the slide remnants may be found. About 100 to 200 feet above the Wolverine sandstone comes the Kearsarge amygdaloid, and about 900 feet above is the Kearsarge conglomerate (10, 11, 12), with which it must not be confused. The Kearsarge amygdaloid or lode is cupriferous in paying quantities for 11 miles, though everywhere the copper is irregularly distributed. It is opened on the Mohawk, Ahmeek, Allouez, North Kearsarge, Wolverine, South Kearsarge, Centennial, Calumet and Tecumseh (LaSalle) properties. Just as conglomerate No. 3 has been used from which to reckon the Baltic lode, and No. 8 to guide us to the Isle Royale and Winona horizon, so No. 9, being but a little way below the Kearsarge lode and separated from it by beds of very characteristic porphyritic ophite, has been used to identify its horizon. One should not, however, forget that any conglomerate and in fact any other bed may be replaced by a slide.

Marvine's conglomerate numbers 10, 11 and 12, seem perhaps to apply to one conglomerate, or at any rate to conglomerates separated by so little trap that all the outcrops may be assigned to one bed without violating any possibilities as to strike and dip. The various crosscuts and deep shafts traversing this horizon around Calumet show but one main conglomerate. On the other hand south of Portage lake there are signs that there really is more than one conglomerate near this horizon so that the one Kearsarge conglomerate may be spilt by lava flows into two or three, a phenomenon that should theoretically and does actually occur.

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*Between conglomerate 8 and 16 was the culmination of volcanic activity.

Above the Kearsarge conglomerate the first felsitic conglomerate is the lucky number 13, the Calumet & Hecla conglomerate, but before we come to it, separated by only four heavy beds of ophite from the Kearsarge conglomerate i. e. only about 450 feet above, is the Osceola amygdaloid.* From this to the Calumet conglomerate is about 400 feet more in which a bed called the Calumet amygdaloid lies. Above the Calumet conglomerate comes the Houghton conglomerate No. 14 and 1,100 feet above the Calumet & Hecla is conglomerate 15, the Allouez or Albany & Boston. Directly above this is a bed of ophite known as the Greenstone, with a capital G, which out on Keweenaw point is several hundred feet thick but much thinner around Portage lake. In the Albany & Boston the Franklin Junior are finding copper, and just beneath the Greenstone, the Cliff found its great success and the Allouez, Central, Phoenix and a score of lesser properties were located.

The top of the Greenstone seems to have been sprinkled with a shower of volcanic ash and then above that the beds became decidedly more feldspathic, of the "Ashbed" type. Luster mottling is less marked while feldspar is abundant and often clotted together. The lava of these beds was perhaps extra viscous and more readily fractured. At any rate the tops tend to pass into a mass of amygdaloid fragments, cemented by red mud rock. These are the "ashbeds" proper.

Copper is widely and rather irregularly disseminated in these rocks and while the Atlantic, Quincy and old Franklin are the only prominent successful mines above the Allouez conglomerate, out on Keweenaw point the Copper Falls, Arnold, Humboldt and a number of others have at one time or another worked with more or less encouragement.

As we follow this horizon to the southwest, we find not merely feldspathic but genuinely felsitic beds developing at this horizon, and we can almost trace it continuously from the end

*This is the main lode of the old Osceola mine and is also opened up on the Calumet. Shafts have also tested it at the Tecumseh and elsewhere.

of Keweenaw point to the Chippewa felsite on Black river and thence to the Wisconsin line. Above the Chippewa felsite the various horizons of Keweenaw point are well defined, as Gordon has shown, the Nonesuch shale, the Outer conglomerate, the Lake Shore traps, the Great conglomerate and the succession of traps and conglomerates beneath. And there as here it is underlain by a great series with relatively little sediment of ophitic flows some of which have very coarse luster mottling, and is overlain by a series where one may infer a dying out of the volcanic activity from the ever increasing frequency with which conglomerates are intercalated between the traps.

The top of the feldspathic or ashbed series may be marked by Marvine's conglomerate 17, which is followed by 18, 19 and 20 in rapid succession, above which the conglomerate becomes the predominant feature, the trap the exception. Tamarack shaft No. 5 reaches a little above the top of the Ashbed group while the longer crosscuts start way down below the Kearsarge conglomerate, giving a section from (3640) feet above the Calumet & Hecla to (1420) feet below say (5060) feet.*

The volcanic activity finally died out and the Great conglomerate was laid down—several hundred feet of conglomerate and sandstone. Among the pebbles of this conglomerate may almost certainly be found types of all the various underlying rocks of the Keweenawan series. The main resistant feldspathic beds such as make up the Calumet conglomerate for instance are still dominant but not so exclusively so. One may even find pebbles, such as agates, which show secondary action in those beds. In particular there are numerous pebbles which appear to be of the type of the intrusive "red rocks" and felsites, augite syenites or gabbro aplites and gabbro which if correctly identified show an erosion of the lower part of the series to such a depth as to expose plutonic rocks. But these also occur in many lower conglomerates. It is more than likely

*All thicknesses given in this paper are those perpendicular to the dip. For horizontal or vertical equivalents one must of course multiply by the sine or cosine of the dip.

that the last flows before the time of the Great conglomerate were feeble and not very extensive so that the base of the Great conglomerate is not drawn everywhere at the same point of time.

After the formation of the Great conglomerate there was one more spasm of eruption marked by the overflow of the Lake Shore trap series. There are some interbedded conglomerates. These produced the characteristic pocket harbors on the end of Keweenaw point. Then the temporarily broken conglomerate formation continued in the making of the Outer conglomerate. No igneous rocks of later origin are yet known anywhere in northern Michigan. As erosion continued long enough, the salient knobs of siliceous lavas seem to have been worn down, and the material became finer. More of the material of the dark basic lavas came into the sediment, especially at the time the dark Nonesuch shales were formed. These are very widely copper bearing judging by the stains. But the copper and silver they contain is very finely divided and their treatment remains an unsolved problem in ore dressing.

Above these darker shales comes a series of red sandstones and shales, the higher beds of which are well exposed near the new stamp mills of the Copper Range mines and all along that shore to Portage canal and are not less than 1,000 feet thick, though the dip is very much flatter than that of beds below.

Pebbles of banded jaspery hematite and other iron bearing rocks do indeed occur abundantly in the Outer Great conglomerate near the mouth of Black river. But these sandstones seem to mark a stage when the Keweenawan rocks had ceased to be the predominant factor in the supply of sediment, which now was derived from the Keewatin and Huronian rocks in large part.

What the relation of these Upper Keweenawan sandstones is to the ordinary Lake Superior sandstone of Potsdam or Upper Cambrian age, such as is so extensively quarried as the Portage redstone and the Marquette brownstone, is still a moot question. My personal belief is that it is very close and that the sandstone which makes the Pictured Rocks and is so closely allied in color, appearance, distribution, attitude and the part it plays in the scenery to that which lines the shore from the canal to Freda is not far removed from it in age.

### SOURCE OF THE COPPER.

For some time after Pumpelly's masterly work on the copper bearing lodes* not much remained to be added. But of late years interesting and pertinent facts have been found by investigators in various other fields, while the progress of mining has shown the continuousness of copper to a depth and for a length along the lode which is in itself suggestive. The depths from the outcrop in the lode is certainly over 8,000 feet, while almost continuous copper bearing ground stretches at times 11 miles or more.

### COMPARISON WITH NEW JERSEY.

At one time this occurrence of native copper on Lake Superior seemed almost unique, but it has ceased to be so, particularly in New Jersey does copper occur in strikingly like surroundings, as has been recently described by Weed and in the Mining Magazine for June, 1906. The association of the Triassic traps of the Palisades of the Hudson and red sedimentaries has for years been recognized as so similar to the Keweenawan rocks that several earlier writers were firmly convinced of their equivalence in age from the lithological likeness alone.

The American Copper Co. have found on Watchung Mount a 2-foot bed of shale under a 600-foot bed of trap which is copper bearing, passing from oxides, carbonates, and sulphides at the surface to native copper at some 700 feet depth, with silver, as in Michigan, and also gold which we do not find in Michigan.

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*Volume I of these reports and Vol. III of the Wisconsin reports. See also Vols. V, and VI of these reports, and my annual reports, especially for 1903 and 1904.

## SALT WATER IN THE MINES.

In the beginning the mine water was not of unusual type, fresh and soft or with only a moderate degree of hardness. A little (waterglass) sodium silicate was characteristic. This continued for the first thousand feet or so. But with greater depth much less water was found, and many writers have spoken of the mines as dry. The flow of water found in first driving a crosscut soon drains off, and little water appears thereafter. At the same time a marked and rather sharp change has appeared in its character. It has become salt and strong not merely in sodium but particularly calcium chloride. It grows stronger and stronger in calcium chloride with greater depth, until it becomes annoying, and if there were any quantity of it would be a serious matter, as it is hard on skin and clothing and pumps and totally unfit for boiler use.

This water seems to have been first noticed in the old Cliff mine by L. E. Emerson, at about 2,000 feet, but is found everywhere in the district, as analyses and tests from the Huron, (annual report for 1902, p. 174), Quincy, (annual report for 1903, p, 243), Franklin, Tamarack, Calumet, (annual report for 1903, p. 166), and Wolverine mines show. Moreover it contains a few grams per ton of copper chloride and is now depositing copper in the Quincy mine. A similar water was even found in a deep well at Freda (annual report for 1903, p. 165) and the the deepest mines of the Gogebic and Menominee (annual report for 1903, p. 155) ranges also strike at the very bottom a water where the chlorine is increasing. The Silver Islet (Canada geological survey, 1887, H. 378), mine of the North Shore also struck this salt water. It is the water used by jewelers to pickle the specimens of copper so abundant in the shops of the copper country, to preserve the beautiful original bloom and luster. It is strikingly and remarkably low in sulphates.

This is shown by analyses made for me by F. B. Wilson, of the College of Mines of samples from the 17th level of the Wolverine mine and the 43d of the Tamarack, as follows;

| | Wolverine. | Tamarack. |
|---|---|---|
| Cl | 15,228.7 | 97,963 |
| Ca | 6,300 | 47,166 |
| Mg | 13 | tr. |
| Ba,Sr | | o |
| Na | 2,731 | 8,278 |
| $NH_4$ | | 829.8 |
| K | | 837 |
| $SO_4$ | 724 | 226 |
| Fe | | tr. |
| Addition | 24,345 | 155,299.8 |
| Total solids at melting point. | | 157,411.5 |
| sp. gr. | 1.022 | 1.135 |

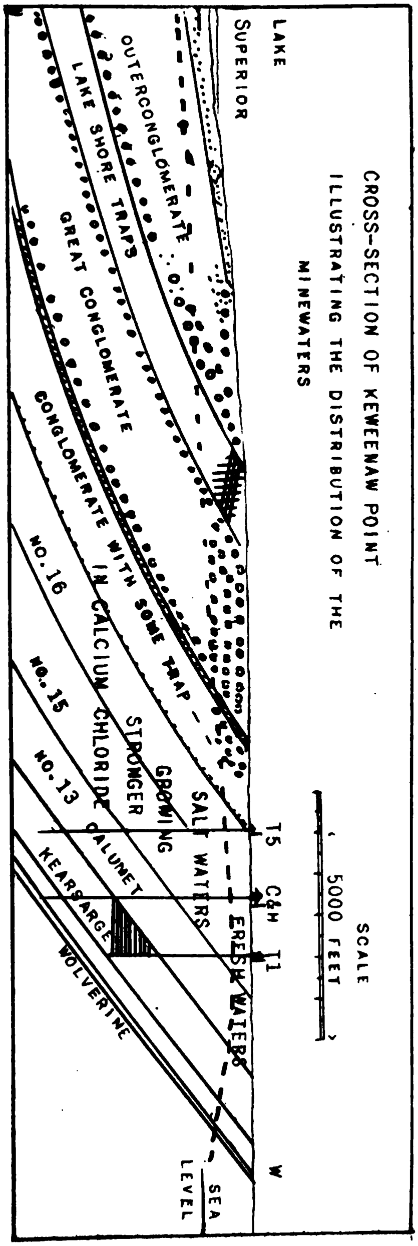
The amounts are in grams per metric ton-parts per million.

Now the salt water may have come in part from an original ocean. The original bubble cavities of the amygdaloids if laid down under water must soon have been filled with the same. Even now the amygdaloids are damper and in the long smoke-begrimmed crosscuts one can often pick them out by the beads of moisture that stand out on the wall.

But various chlorides, especially ferrous and ferric, and chlorine emanations are found around volcanic vents. Brun has recently found that hdyrocarbons or carbides, nitrides and silico-chlorides are normal constituents of lavas.

R. T. Chamberlin, of Chicago, finds indeed that most igneous rocks yield about one to two times their volume of combustible gas. Such a gas and the substances found by Brun are powerful reducing agents.

Combustible gas has been found in mine waters, notably at Silver Islet, but also at the Calumet & Hecla. It was natural to attribute it to decaying timbers but that explanation seems no longer necessary. So, too, Pumpelly's explanation that native copper was reduced from combination by ferrous salts, though perfectly possible and plausible, becomes unnecessary if we suppose carbon compounds originally present in lava or sea water. It may be these compounds which in oxidizing have


CROSS-SECTION OF KEWEENAW POINT
ILLUSTRATING THE DISTRIBUTION OF THE
MINEWATERS
LAKE
SUPERIOR
OUTERCONGLOMERATE
LAKE SHORE TRAPS
GREAT CONGLOMERATE
CONGLOMERATE WITH SOME TRAP
NO. 16
NO. 15
NO. 13
KEARSARGE
WOLVERINE
CALUMET
IN CALCIUM CHLORIDE
STRONGER
GROWING
SALT WATERS
FRESH WATERS
T5
C&H
T1
W
SEA
LEVEL
SCALE
5000 FEET

produced the calcite which is the mineral most intimately associated with copper. One can readily find crystals of Iceland spar ($CaCO_3$) intergrown with native copper whose virgin luster is thus beautifully preserved. Sometimes the crystal form of calcite (the dogtooth scalenohedron, etc.) is plated with copper, and the growth of calcite continued.

Now carbon dioxide and carbonates are almost absent from this lower water, though they are extensively present in the rocks.

It is easy then to suppose that the slow oxidation of hydrocarbons and carbides originally in the beds has furnished the carbonates and reduced the chlorides and been the cause of much of the alteration of the rocks, and we are not compelled to look at either the surface above or to abysmal depths below for the source of the copper and the water that deposited it. The copper may have been in the original lava, or in original soluble chlorides, or in the original ocean, and have slowly segregated as the water slowly migrated.

I should say, however, that Van Hise and Smyth (Vol. VI, Part I, p. 216) are inclined to look at the copper as later introduced, from a deep source. But this brief guide to the district already more than once visited by this Institute, cannot go into detailed argument, but rather presumes acquaintances with the earlier literature and aims to call attention to the newer facts and theories.

## ALTERATIONS.

Pile up a series of heavy massive beds (traps) and open porous spongy ones (amygdaloids) like a layer cake, and then tilt the pile and there can be but one result—a slump and sliding of the upper beds and a crushing of the porous ones, as shown in Fig. 4, until by a process of shattering and filling up and cementation of the porous beds with new minerals they are made of nearly the same gravity as the rest and strong enough to stand the pressure. This is what has happened. It would be far too great a task to describe all the new minerals thus produced. But even the most casual visitor will have a chance to see in the mine dumps and at the stamp mills the soft white cleavable calcite, the white or colorless glassy hard quartz, the yellowish green epidote, and the darker bluer greens of the chlorite (delessite) group, and serpentine. Prehnite, white with a faint greenish tinge, is a common associate of copper. Laumonite, reddish and readily crumbling is not so

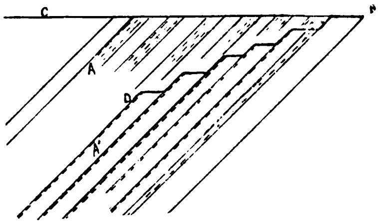



Figure illustrating the effect of slump in a series of traps and amygdaloids, the amygdaloids being originally vesicular porous beds as thick as the traps but crushed to a fraction of their original thickness, in which process the line CB takes the position BD and the bed A sinks to A'

favorable a sign of copper. Datolite, almost like porcelain, often with beautiful flesh, and other tinges, is one of the last minerals formed.

In general, laumonite, epidote, quartz and prehnite tend to antedate the copper, calcite and analcite are about coeval, while datolite and orthoclase are often later, but there is a good deal of overlapping. Sulphates like barite and selenite are rare and late comers and like the analcite and silver seem rather confined to the upper levels. I am inclined to think too, that the interesting sulphides and arsenides, the lead colored chalcocite, the tin white chloanthite, the pale reddish nickeliferous Mohawkite, and Keweenawite, are also relatively superficial.

One of the striking factors in the development of stamp mill practice in the past decade in the copper country is the replacement of the old fashioned slime tables by the diagonal tables of the Wilfley, Overstrom and Deister pattern, and a noticeable and beautiful feature in some of the mills is the production of bands of different colored minerals arranged according to specific gravity. Next to the copper red there may be a lead colored band of chalcocite present. The yellow green band of epidote may next appear before we come to the dull maroon or other color of the general rock.

The amygdaloids sometimes have the original structure and round bubbles fairly well preserved, and filled in either with white calcite, or quartz, or chlorite. At other times they are brecciated, that is all broken up. Where great sliding has taken place the rock is reduced to a greasy red clay called fluccan. This the miners used to use for candlesticks. It is much more greasy than the red clay or sand which washed into the irregular cooling and shrinkage cracks, and formed what have been called clasolites. The trap is often relatively unaltered but when altered the change is generally to chlorite and to epidote, in other words to soft dark green or hard yellowish green, and we often find this directly under the amygdaloid or in bands.

### SHEAR ZONES AND CHUTES.

To return to our simile of a pack of cards, if we bend a pile of paper and one part of the pile more than the other, we shall find a belt where the paper tends to gape apart. (Fig. 5).

So in the uneven tilting and slumping to which the formation has been subjected we find at times belts of trap which have been much fissured and shattered, in which secondary action and at times copper formation has gone on, by no means confined to any one amygdaloid, though normally the giving way and readjustment would naturally follow the weaker beds,

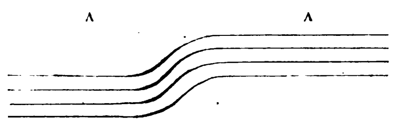


Figure to illustrate gaping of pile of cards or beds of rock when bent.

the sandstones and the amygdaloids. But if we have a stress whose principal directions are not exactly at right angles to the bedding of the rocks, there will be a diagonal structure formed. The stress will be resolved into a strain and slipping along the weaker beds until the other components have become great enough to cause the yielding to jump across through a heavier trap bed, shattering it on the way, and producing a shear zone. In many cases there would be in such a belt a tendency to tension and open places left to be filled in by new matter.

The Quincy mine does not appear to be confined to any one amygdaloid and the Baltic lode also appears to be such a shear zone. There certainly is such lack of symmetry in the stress to which the range has been subjected. Gravity must act vertically rather than down the beds. And we also have to note the tendency of the faults to be to the right going to the east and northeast.

## SURFACE GEOLOGY AND DISTRIBUTION OF FLOAT COPPER.

After the closing of the up-tilting the copper range uplift may have continued in a massive way, but about the time the hardwoods first became abundant a sandstone was formed in the Mesabi range (Leith on the Mesabi Range, U. S. G. S., Monograph 43, p. 189), and the ocean may possibly have reached this region, too, but no trace of such sediments have yet been found. Probably before this time the surface was reduced to a comparative level, such as the plateau from the Quincy to the Calumet, and at some time since the Cambrian sandstones mantled the range (possibly when emerging from the Cretaceous sea) rivers seem to have established their course across the range, marking out valleys such as those now occupied by the Ontonagon river and Portage lake. These valleys may have been cut deeply in the era of elevation preceding the recent ice age, which is marked by the formation of caves such as the Osborne caves, and by the deep valleys in the rock surfaces, now filled with drift, whose soles are at times below sea level. At the same time the minor tributaries in their erosion brought out the rock structure, generally leaving the harder traps in ridges. When the ice age came on the earlier center of collection and distribution seems to have been northwest of Lake Superior. It is called the Keewatin center. Later the ice moved from the east, from a center in Labrador called the

Laurentian center, and reaching Lake Superior moved out from it. Around Portage lake the ice actually moved 10° north of west. This direction of ice motion is beautifully marked near the Calumet, Arcadian, Quincy, and Isle Royale mines. One can see the shock and lee sides of the motion, the grooves and trails left by harder knobs.

The ice front was naturally perpetually oscillating and the directions of ice motion and transportation, streaming away from the center of distribution and finishing at right angles to the front, also shifted. Hence copper may be found either side of its parent ledge, but that at the surface which is most likely to be found is left by the last ice motion—more probably that from Keweenaw bay—and farmers, plowing their fields near the canal reap a rich harvest of nuggets of copper which may have come from the Franklin and Quincy.

Deposits direct from the ice are known as "till" and are unassorted, but where the rock under the ice sheet which it eroded was mainly sandstone, the derived deposits are naturally pretty sandy. But there were enormous quantities of more assorted material washed out from the ice front by water from the melting ice, and deposited in sheets known as sand and gravel plains, irregular masses known as kames, and long ridges known as eskers. Along lines where the ice lingered some time the deposits are extra heavy, and mark moraine lines.

Keweenaw point retarded the ice advance and held its retreat and to some extent a series of cusps or re-entrant points were made in the ice front on the back of it while sandy moraines were dumped on its flanks. A re-entrant point at one stage of retreat seems to be near Centennial Heights north of Calumet. Another hill of sand, Wheal Kate, (1,508 A. T.), towers to the south of the Atlantic mine and Mill Mine Junction and is readily recognized from the hills either side of Portage lake. It is part of a heavy moraine which goes clear round Keweenaw bay and for miles out the drift is extra thick.

Working through this coating of light, often "quick," sand makes exploration and mining difficult, and is the probable cause of certain districts being less rapidly developed.

In front of the ice sheet the water was ponded to a height very much greater than that of the present lakes, and the shores of Portage lake are very plainly terraced by these waters which have receded with halls at various levels. The beaches 480 feet above the lake (1082 A. T.) and lower are very well marked where they cross the electric road, and run into the spit near the Quincy mine and also near Mill Mine Junction, and the delta of Huron creek is a striking feature. But this is not the upper limit of wave action, which on the west side of the Copper Range is, if I am not mistaken, 1,200 feet or so A. T.

A knowledge and study of these terrace lines should be a great help in planning railroads and townsites.

# THE IMPORTANCE OF THE ORDINARY SANITARY PRECAUTIONS IN THE PREVENTION OF WATER BORNE DISEASE IN MINES.

By B. W. Jones, M. D., Vulcan, Mich.

In entering upon the consideration of the subject of sanitation, or the prevention of diseases that are known to be produced by minute organisms called bacteria, microbes, or parasites, it is not my purpose to consider the diseases so produced; nor would it be possible, in a paper of this kind, to discuss the intricate problems in bacteriology; the solution of which have led to our present knowledge of the subject of sanitation in general.

Men who have devoted their whole lives to the solution of these most important problems, have shown that the great majority of the diseases with which we have to contend are caused by those minute living organisms and that water plays a most important part in their transportation and distribution.

They have demonstrated the difference which exists between their growth in sterile water, where they are not interfered with by other germs, and their growth in ordinary running or stagnant water, in which they are exposed to the destructive action of other microbes. It is owing to the discovery of this fact that filter plants can be constructed for the purpose of purifying water. The filter removes all or most of the microbes, while those more fit to thrive in the water of the filter beds, destroy by devouring or chemically changing those less fit.

A difficulty now arises which emphasizes more than anything else, the necessity of providing water for domestic purposes uncontaminated with disease germs, for these germs, during the course of their development or when dead or dying, generate soluble organic chemical compounds extremely poisonous in their nature, and being soluble, irremovable by filtration. It will be seen then that the purification of water containing decomposable organic chemical compounds is difficult and the importance of obtaining water free from the organic matter, on which disease germs live and therefore incapable of supporting them, can be understood.

Typhoid fever is undoubtedly the most prevalent and the most dangerous water borne disease with which we have to contend, particularly in opening up a new country or starting up a new mining camp. That it is by drink, more than by any other method, that the disease is carried from man to man, there can be no doubt. The lighter forms of typhoid are often more dangerous to a community than the more severe forms; because the latter are sooner detected, the patients can receive proper care and the excretions from the body can be removed and destroyed or rendered harmless. But in the lighter form of the disease sometimes called walking typhoid, the infected person may be able to go about his work as usual, during the greater part, and no doubt often through the whole course of the disease.

There is a class of restless miners who wander about from camp to camp, who from the irregularity of their lives, and careless habits in regard to food and drink, are more apt to become infected than others and are peculiarly liable to spread the disease. If an outbreak should occur through such an agency, the innocent and unsuspecting ones who drink of the poluted waters are the sufferers; the cause of the outbreak remains a mystery and the guilty one escapes, with to him, but the slight inconvenience of a little diarrhœa, with loss of appetite and a sense of weakness, all of which he has nobly combated and successfully conquered with the good old remedy, his faithful standby in all his troubles, happily ignorant of the fact that it is the cause of all his ills. There is every reason to believe that this microbe lives as a saprophyte, as well as a parasite, that is to say, that it is able to maintain its existence through many generations independent of man. Thus it happens that the disease can become habituated to certain places. Now should the surrounding sanitary conditions be bad and an outbreak occur, it will continue and spread, perhaps governed by influences which may have to do with the water, but do not seem to have anything to do with the original water infection.

How important is it then, to strive to maintain strictly good sanitary surroundings, where the source of the outbreak, the poluted water, can be defintely located and the cause easily removed.

Although typhoid fever, of all the diseases, the germs of which are distributed by water, is the disease in which we are perhaps most directly interested, the disastrous effects of which we can most clearly see and feel, when it has gained a foothold where conditions are favorable to its spread, there are other diseases caused by parasites which infest the human body and cause all kinds of disordered function, anemia, pain, hemorrhage, convulsions, tumors, and in many instances, death. Among them may be mentioned "tapeworm." This disgusting parasite exists in the form of cysticerci, or immature worms in the flesh of fishes, pigs, cattle and many other animals. By eating fish, or improperly cooked flesh of animals infected with these parasites, man becomes the distressed and unwilling, though perhaps unsuspecting host of the fully developed worm and may go about for a long time, perhaps for years, the supposed victim of chronic dyspepsia. The worm now fully matured and grown to an enormous size, deposits its eggs in great numbers within the intestines, to be carried off in the excretions and deposited, if in the mine in any out of the way place most convenient at the time, perhaps where they will find their way into the sumps and be pumped to surface, be scattered broadcast through the streams or lakes or over the pastures and infect fishes or animals that devour them.

The eggs of the various stomach worms or round worms, may be distributed by water. Instances are known and have been recorded of outbreaks, which might in truth be called epidemics, the cause of which could be traced to no other source than the use of drinking water into which the eggs had been carried.

The diseases caused by the liver-fluke, the guinea worm, and filarie that live in the blood and lymphatic vescicles, are all filth diseases and water borne. The danger to us, however, from the last two mentioned is more remote. Their natural habitat is the tropical countries, Arabia, Algeria, Egypt, India, the western coast of Africa and South America. The danger lies in the unrestricted emigration from these pest ridden countries, where as in Algeria, no man is sure that his intestine is not the home of a parasite, where sanitary laws are utterly unknown, where profound ignorance, combined with shameless filth and loathsome habits, permits the unrestricted distribution of disease, excrements of all kinds contaminating the water, and the soil, the food and even the air.

Uncinariasis, or hook-worm disease, also known as ankylostomiasis and in some countries, as in Westphalia and Hungary, where it has gained a strong foothold in certain large colleries, is known as miners worm disease. It, however, is not confined to miners, but includes all classes, the rich and poor, the young and old alike.

The chief symptoms are anemia, loss of strength, pale and sallow complexion, dwarfed development, both mental and physical, and preverted appetite, chiefly dirt eating.

In mines where the disease has become established, the result has been disastrous; not alone in the suffering it has caused to those who have contracted the disease, but in financial loss to the mine owners as well.

The life history of this parasite, first described by Dr. Looss, of Cario, Egypt, and since fully confirmed by others, is curious.

Existing as fully developed worm in the duedenum, or the upper part of the small intestines, the eggs are laid in large numbers. In the intestines, owing chiefly to the want of oxygen, they undergo no further development but are passed off in the excretions. When, meeting with favorable conditions of heat, air and moisture, they develop into larvae, which may be able to retain their vitality for months. The larvae coming in contact with the skin, penetrate a small vein, whence they are carried to the right side of the heart and from there to the capilaries of the lungs. They now penetrate the thin walls of the air vescicles, into which they escape and make their way along the bronchial tubes into the windpipe, where they are coughed up into the mouth and swallowed. They now proceed to the stomach and from there to the duodenum, where owing to their advanced development, they are able to attach themselves by their hooks to the mucous membrane and by sucking the blood of the victim, and at the same time excreting a poisonout substance that renders the blood more fluid, set up the train of symptoms above described.

These parasites have no doubt existed for ages in countries like Arabia, Algeria, and portions of India; but it is only within recent years that the nature of the disease produced by them has been worked out to a thorough understanding.

The disease has existed for a long time in Porto Rico, where its presence was tolerated, until after the war with Spain our sailors and soldiers became infected with it. Since then the Porto Rican government has spent $20,000 in the study of the disease; the Porto Rican anemia commission having treated over 23,000 patients.

Dr. C. C. Bass, of New Orleans, who is now making a study of the disease in the southern states and especially in the state of Mississippi, in a recent article states that the reports of the local physicians show that 6 per cent. of the population of Harrison county have the disease; 25 per cent. of the population of Pearle River county have it and 20 to 25 per cent. of the population of Marion county are infected, and himself adds, that he thinks these figures are too low, that a careful examination would show that 50 per cent. of the rural population of Marion county are infected to some extent and that several other counties in the southern part of the state are equally as badly infected. Quoting further, Dr. Bass says, "I believe that the state is widely infected with a disease slower yet more deadly either directly or indirectly, than yellow fever, tuberculosis, malaria, or small pox. That it is dwarfing and destroying both mentally and physically a very large percentage of the youth, and sapping the very life blood of many of her men and women."

This is indeed a timely warning. It shows us that the disease is spreading rapidly and tells us that the danger is not remote, for like other parasitic diseases, or walking typhoid, it can travel anywhere, and being a water borne filth disease, will gain a foothold if permitted.

What then is to be done? Understanding that preventable disease means preventable filth it appears to me that the most important thing to be done, is to spread a knowledge of preventable disease among the people, that they realizing the danger, may avoid it.

To those responsible for conditions in the mines falls the duty of preventing the spread of infection by means of mine water.

In cases where it is possible that the water coming through the rocks into the mine openings, may come from other mine workings or contaminated surface sources, its use should be prohibited and pure water provided.

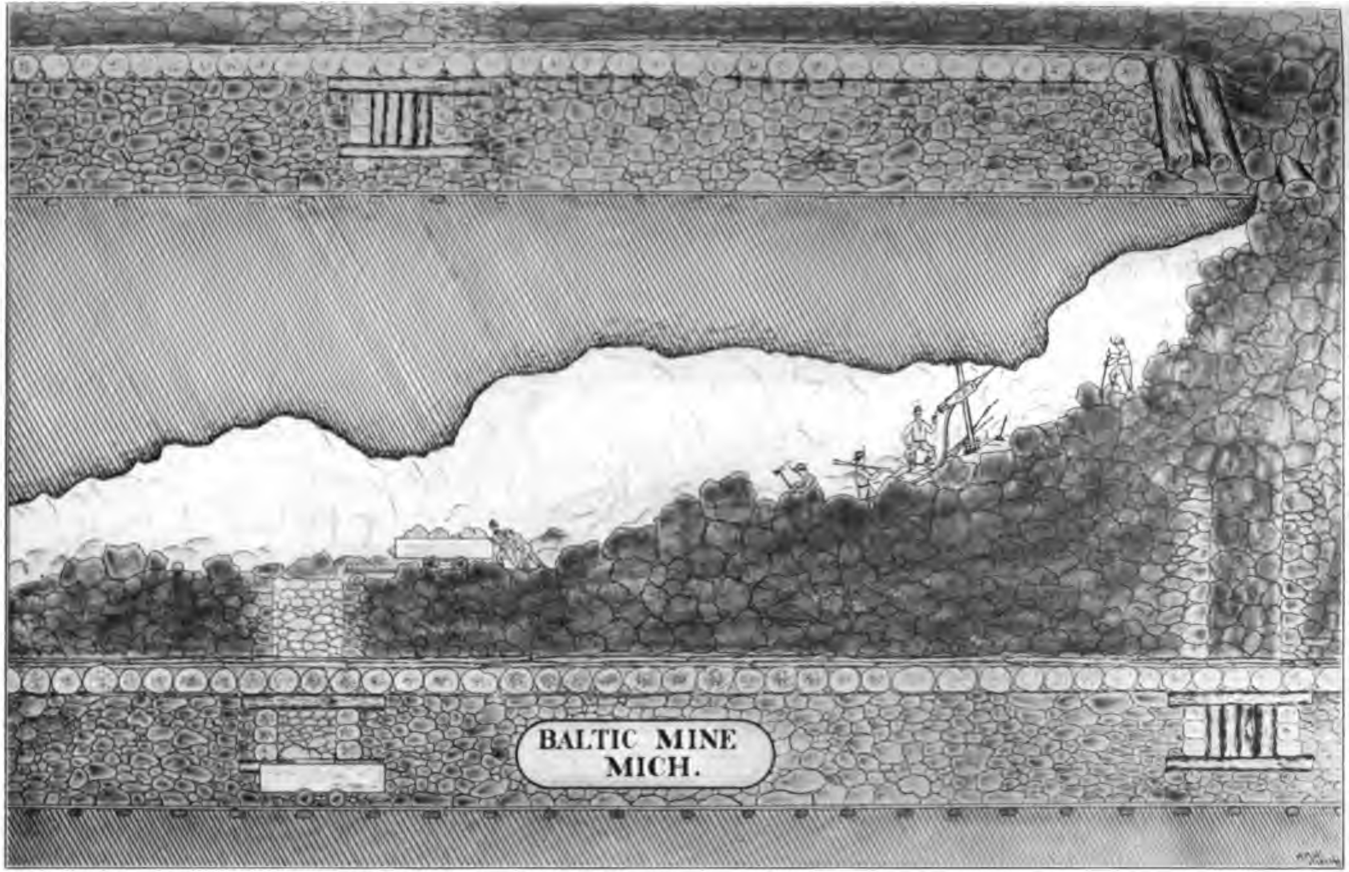
Drifts and crosscuts should be made so that stagnant pools will not collect in places where the miners are obliged to walk. Water from the mine passes into streams and lakes and rivers and may be the source of danger. To prevent this, much can be done by providing plenty of suitable and convenient places for the excrements of the body underground as well as on surface and by the hearty co-operation of the men with the management, in the rigid enforcement of a few simple rules regarding the use of them.

BALTIC MINE, FILLING SYSTEM.

Showing Cross Section on the Lode. (Note Upper Extremity of Chute With Post on Top to Support Back of Stope.
(Model in Michigan College of Mines.)

BALTIC MINE.
Showing the Four Shaft Rock Houses and the Two Power Plants.

BALTIC MINE.—FILLING SYSTEM.
**Showing Method of Stoping on Top of Filled Ground.**




THE FILLING SYSTEM, SHOWING LONGITUDINAL SECTION ON THE LODE
(Drawing by Mr. E. N. Wold, Michigan College of Mines.)

DISCUSSION ON DR. JONES' PAPER.

MR. MACNAUGHTON: I do not know whether Mr. Kelly is prepared to invite discussion on this paper, to answer the numberless questions which might arise.

MR. KELLY: The subject of mine sanitation is having the consideration of other mining institutes. About one year and a half or two years ago, in the proceedings of the Institution of Mining and Metallurgy of London, England, there was an extensive paper by three gentlemen on the subject of miner's phthisis, or lung diseases. In Great Britain the vital statistics show not only the number of people who die of each disease, but also the occupation of those who die of each disease; so that it is possible to compare the number per thousand who die, we will say, of miner's lung disease among the miners of Cornwall, with the number who succumb to the same disease among those who work in the coal mines and in the north of England iron mines, and it appears that this disease is especially prevalent in the Cornish mines. The article to which I refer considers what may be the causes of this pulmonary disease, whether it is due to a dry dusty atmosphere, or to the impurity of ventilation, or to the smoke, or to the lack of light, or to some other causes, and the conclusion is that it is due principally to the dry dust which affects particularly the drilling machine men, and can be prevented by using sprays of water either in or outside of the drill holes.

Just before I left home I picked up a copy of the Mining Journal, an English publication, and I noticed the last part of an abstract of a paper read before the Chemical, Metallurgical and Mining Society of South Africa entitled "Mine Sanitation on the Rand," by Donald Macaulay, M. A., M. B., C. M., and Louis G. Irvine, M. A., M. D., B. Sc., which deals with this same question. In it I see the following: "The West Australian Commission definitely lay it down as a recommendation that no white worker proved to be suffering from tuberculosis of the lungs should be allowed to go underground. For the affected man to continue underground work is merely suicidal, and for his mates the risk of working in close places in company with anyone affected by tuberculosis is certainly a definite one. We would urge, therefore, that the government should seriously consider whether it would not be wise, in the interests of all concerned, to follow the recommendation of the Australian commissioners." So in these three British countries, England, South Africa and West Australia, they are considering carefully the question of lung disease among the miners. As yet this question has not been brought forcibly to our attention but we should be prepared to meet the danger if it arises.

Then in the proceedings of the Institution of Mining Engineers of England there has recently been an article on the subject of miner's hook worm disease, which is especially alluded to in Dr. Jones' paper. In Hungary it has been almost impossible to work the mines on account of this disease, and in Westphalia they do not permit a man to go underground unless he has passed through an examination, and until he has been under observation for—I think it is five or seven days. The larvae from this microbe is found on the timbers in the mine and for perhaps four feet above the bottom of the level, so that anyone passing along may get them on his hand, and from there they pass through the system, as described by Dr. Jones.

With these facts before us, the subject of mine sanitation is of the utmost importance. I have forgotten pretty nearly all that I learned at college, but I recall distinctly that in the toilet rooms there was this notice: "Clean and comfortable water closets are an indication of advanced civilization." Judged by this criterion I fear that many of our mines must be classed as simply barbarous.

In some cases no restrictions are laid on the deposit of excrement provided it is off the main traveling roads and provision for its disposal in a sanitary manner is far from being the universal custom. I would like to hear what is being done in some of the other mines, in the way of sanitary regulations.

MR. MACNAUGHTON: Are there any further remarks to be made on this subject? We hope that all the sanitary measures are not to be left to Mr. Kelly to carry out himself.

DR. AUGUSTUS KOENIG: Mr. President, I am not a member of the Institute, but I was very pleased to hear the very instructive paper that Dr. Jones had prepared, and also the very logical remarks and discussion of Mr. Kelly. With regard to miner's phthisis we have three diseases that are spoken of in medicine respectively as anthracosis, calcicosis and siderosis. Anthracosis is a consumption that we find in the miners, produced by the inhalation of coal dust. Calcicosis is exactly the same disease, only we find it in those people whose business it is to cut marble; in other words marble cutters; while siderosis is a disease in no way different from the other two, but which we find in grinders of steel. These men inhaling fine particles of steel.

Now an examination of tuberculosis or phthisis, whichever you choose to call it, is not produced by the inhalation of these particles, but these particles produce an irritation followed by a congestion and when this congestion is kept up continuously from day to day it will produce a permanent change in the tissue of the lung, or of any tissue, in fact, and the lung tissue itself becomes replaced by what we call, or what is known as connective tissue. This connective tissue is characterized by the fact that it has a very low vitality. It has no blood vessels and therefore is very easily broken down by disease. Now when a man in this condition inhales germs of tuberculosis, of course these germs find a very fertile soil upon which they may grow, and in this way produce tubercular diseases. This condition we find in the workers in these three trades I have mentioned.

The same, I think, may possibly also occur in these mines, or the mines located in this district. I am not sufficiently familiar with the interior workings of these mines to know just exactly how much dust there is and how that dust affects the men, or the character of the disease that arises from the workings. I should, however, say if there is a great deal of dry dust formed, it would undoubtedly lead to the same condition. Now if miners who are infected with tuberculosis, not merely with the formation of connective tissue in their lungs, but those who actually have the disease, are allowed to work in the mines, they will undoubtedly infect others through their expectorations. These expectorations contain the germs of consumption, and if these germs are then inhaled by the other miners, you can readily see that the spread of disease will be very rapid, and be very fatal to the men working in this district. For this reason I think that a strict examination into the health of the miners would do a great deal to remedy this condition. In other words not to allow any man who is infected with tuberculosis to work in the mines and become a menace to other workers.

The lung of a man suffering from anthrocosis, when it is removed after death will be as black as ink, and will be hard, and will have lost its character, or characteristic appearance to a very great extent, and this same condition, of course, also obtains with the other diseases mentioned, except that the color is not black.

Now with regard to the providing of suitable water closets, I think this is also of very great importance. Typhoid fever, as Dr. Jones suggested, as well as many other infectious fevers, are produced by taking in the germs of those diseases in which the infectious material is found in the excrements coming from other persons. For this reason if men are allowed to evacuate the bowels indiscriminately wherever they see fit, they may very naturally become a source of infection or a menace to other workmen. Just what means are provided for this purpose in the mines I am also unfamiliar with. I know, however, that in country towns where sewage systems are not established, that it is frequently customary to have in the closet a box into which the excrements fall, and always after a person has been at stool, the forces are covered with a small shovelful of lime. I think this method can be easily practiced in a mine. It would not perhaps be necessary to use lime, but lime is very cheap. Ashes can also be used. There are many other disinfectants which could be utilized in the box, and thereby the excrements would be disinfected as soon as they entered the box. These boxes could then be removed from time to time, and buried or incinerated. Without the use of disinfectants there might be some danger of spreading infection while removing the boxes from the mine, as a portion of the material might be spilled, and in that way be a source of infection. Therefore by the use of disinfectants the remedy, I think, would be very simple.

# THE IRON ORE DEPOSITS OF THE ELY TROUGH, VERMILION RANGE, MINNESOTA.

BY C. E. ABBOTT, HAZEL GREEN, WIS.

The Ely district occupies a portion of the Vermilion iron range, Minnesota. It is located in St. Louis county and adjacent to the city of Ely.

The area to be described in this paper is about one square mile, and comprises a group of five producing iron mines. These mines are leased and operated by the Oliver Iron Mining company, the iron mining division of the United States Steel corporation.

## HISTORY OF EXPLORATION AND DISCOVERY.

*General.*—Iron ore was first mentioned as occurring in the Vermilion district by J. G. Norwood in 1850. Later explorers also found iron ore, but until 1875 nothing much was done towards exploration. Their first work was done near Tower and upon what are now known as the Lee Hill deposits. (a). In 1884, 62,122 tons were shipped from this area.

In 1883 outcrops of ore were found by H. R. Harvey in Section 27, T. 63 N., R. 12 W., (b). These were further tested and later opened up. Thus were the great ore deposits of the Ely district first discovered. From that date development has progressed rapidly until these mines today produce an enormous tonnage of Bessemer ore.

*Chandler Mine.*—The Chandler mine, located at the extreme west end of the Ely trough was first discovered.

(a. b.) The Vermilion iron bearing district, J. Morgan Clements, monograph XLV, U. S. G. S.

Here the ore came within a few feet of the surface at one point. In 1886 exploratory work, by means of test pits and trenches, proved up a large amount of ore.

When the Duluth & Iron Range railroad reached Ely late in 1888, shipments were begun and 54,612 tons were forwarded during that season. The first shipments were made from open cut workings. Later, as the ore pitched to the east under the jaspilite capping, it became necessary to sink shafts and conduct underground mining. Five shafts in all have been sunk upon this property. All of these, with the exception of the last, have been abandoned for various reasons. No. 5 shaft is down to the 23rd level at a vertical depth of 843 feet below surface. This level, which is 547 feet above sea level, is the deepest working in the property.

The operation of this mine has been continuous since first begun.

*Pioneer Mine.*—Developments in the Chandler, lying to the west of the Pioneer, prompted explorations upon this property. A great amount of work was done from small vertical shafts. Considerable drifting and diamond drilling was also done. The ore was found to run in small bunches in the jaspilite, and not until much greater depth was reached did the main ore body appear. Considerable ore was found by means of these shafts, but they were merely exploratory in character.

The two main hoisting shafts now in use are "A" and "B." "A" is a five compartment vertical shaft, and "B" a 70° three compartment, steel lined shaft. "B" shaft dips to the east and follows the pitch of the ore body in that direction. Both shafts are sunk to the 12th level, which is 1,057 feet below surface. This depth corresponds to an elevation of 306 feet above sea level, and is the greatest yet reached in the district.

The first shipments from this property were made in 1889 when 3,100 tons were forwarded.

*Zenith Mine.*—The Zenith mine was first explored in

1890. The iron bearing formation was located by means of test pits and trenches. Later, vertical shafts were sunk for the purpose of exploration.

At present there are two vertical shafts at the property. No. 1 shaft has been sunk to a depth of 806 feet, to what is called the 10th level. This level is 599 feet above sea level. This shaft is at the present time the main producer. No. 2 is a vertical, four compartment shaft, and is now down to a depth of 1,023 feet. A level is being opened out at 901.5 feet below the shaft collar. This level is 599.5 feet above sea level. This shaft will eventually become the main producer of the property. It is located so that the eastward pitching ore body can be easily intercepted by crosscuts driven north.

The first ore shipped from this property was in 1892, and aggregated 16,789 tons.

*Savoy Mine.*—The Savoy mine lies at the extreme east end of the Ely trough. Practically the same methods of explorations used in the other properties were used here.

There are at present two shafts upon the property. No. 1 shaft was sunk in the hanging wall, based upon the showing in a vertical drill hole. Later developments made it necessary to abandon this shaft, and No. 2 was sunk in what had proved to be the footwall. No. 1 is a three compartment, vertical shaft, while No. 2 is a three compartment shaft inclined at 83 degrees 30 minutes. No. 2 is bottomed at the 3rd level at a vertical depth of 714 feet, corresponding to an elevation of 645 feet above sea level.

*Sibley Mine.*—The Sibley mine lies between the Zenith and Savoy and was discovered by development work done in the Savoy property.

There is but one shaft, a three compartment, vertical. This shaft is down to a depth of 727 feet, or 644 feet above sea level at the 3rd level. The 2nd and 3rd levels, as also the upper workings, have been connected with those of the Savoy. The Sibley ore body is the western extension of the Savoy deposit.

The ore from the Savoy and Sibley properties was at first shipped as though from one mine. The first shipments from these properties occurred in 1899, and reached a total of 90,653 tons for the season.

### SUMMARY OF GENERAL GEOLOGY OF THE RANGE.

The succession of formations in descending order is as follows: (a.)

Succession of formations in Vermilion district.

Algonkian—Keweenawan—Dolerite and basalt dikes; Duluth gabbro and Logan sills.

Algonkian—Upper Huronian—Rove slates; Gunflint formation.

Algonkian—Lower Huronian—Dolerites and Lamprophyric dikes; Granite; Knife Lake formation; Agawa formation (iron bearing); Ogishke conglomerate.

Archean—Granites; Soudan formation (iron bearing); Ely greenstone.

The Vermilion district is one that has been subjected to very great movement. The rocks are folded in a very complex manner so that, as a result, the formations appear to be distributed in a very irregular manner.

Intrusions of later age have made the structure even more complicated.

"Looked at broadly the Vermilion district may be regarded, however, as a great complex synchinorium mainly bounded on the north by granite formations of Archean age and on the south by plutonic igneous rocks, including granite of Huronian and gabbro of Keweenawan ages."

There are iron bearing formations in the Archean, Lower Huronian and Upper Huronian. The Soudan formation in the Archean is the only one of these formations that has produced iron ore in merchantable quantities.

### GENERAL GEOLOGY OF ELY TROUGH AREA.

In the immediate vicinity of Ely the Archean and Lower Huronian formations alone are present.

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(a.) The Vermilion iron bearing district, J. Morgan Clements, monograph XLV, U. S. G. S.

The succession of formations is as follows:

Succession of formations in Ely district.

Algonkian—Lower Huronian—Intrusive dikes (dolerites and lamprophyric); Giants range granite; Knife Lake slates (slates and greywackes); Ogishke conglomerate.

Archean—Vermilion series—Granite of Basswood lake; Soudan formation (iron bearing formation); Ely greenstone.

*Ely Greenstone*—The Ely greenstone forms the most prominent surface exposures in this area. This rock is present in prominent ridges upon all sides of the belt of iron formation; more particularly at the north, west and south sides of the Ely trough.

The greenstones of this area have originally corresponded in character to basalts. They have undergone a large number of changes and consequently do not show any of their original characters. The changes have affected both their chemical and physical structure.

The greenstones in general may be said to vary from light to dark green in color with some brownish greens. They weather to a light greenish grey, while fresh surfaces are always darker in color. They are generally massive in structure, but in many cases are shistose. Their textures range from granitic to porphyritic. Definite indications of bedding are entirely wanting. They have been broken, mashed and folded, and contain many veins of quartz which have been developed in joints and fractures.

*Soudan Formation.*—The Soudan formation in this area contains all of the known ore deposits. Exposures are not very nurmeous in close proximity to the trough there being a covering of glacial drift over almost its entire length. The Soudan formation is the oldest sedimentary formation in the district. It has been divided into a fragmental series and into the iron formation proper.

The clastic portion of the formation underlies the iron formation proper, and consists of a conglomerate at the base grading upward into finer grained rocks. The conglomerate lies upon the greenstone and contains pebbles derived from it. This lower clastic formation is rarely present, and where found is very thin. It has a very important bearing as it marks a transition from the period of volcanic work to the period of sedimentation.

The jaspilite, or iron bearing formation, proper, consists of various colored cherts, banded with hematite. It consists in most cases of alternate bands of jasper and hematite. The jasper frequently has a brilliant red color due to the pressure of blood red hematite, while the hematite bands are steel grey.

The Soudan formation has been subjected to all of the great movements which have affected the older greenstones. As a result it has been folded in a very intricate manner. This folding at some points has apparently taken place while the formation was in the zone of flowage, for the bands have been bent back upon themselves without a sign of fracture.

However, as the ore and jasper of the Ely trough are at present in a brecciated condition in places, it is evident that extensive movements have taken place while they were above the zone of flowage.

The various rocks of the Soudan formation are, according to Van Hise, derived from a silicious iron bearing carbonate (a).

## LOWER HURONIAN.

The Ogishke conglomerate was not found at any point in the area. Where it should occur geologically it was probably destroyed by the great shearing stresses, and thus it was impossible to differentiate it.

The Knife slates are well exposed in the area, and especially in the vicinity of Long lake, which lies to the north of the Ely trough. Where found they had a considerable variation in color and texture. They have a greenish grey color sometimes light green in surface exposures. Where found

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(a) Iron ore deposits of the Lake Superior region, C. R. Van Hise, 21st Ann. Rept., U. S. G. S.

underground they were dark bluish black in color. Their grain is very fine in most cases. They have been highly metamorphosed and have a characteristic cleavage in most cases. Their original bedding planes are not distinguishable.

Mr. J. Morgan Clements has mapped the rock of the Lower Huronian as lying in contact with the iron formation upon the north side of the Ely trough, in the vicinity of the Zenith, Sibley and Savoy mines (a). The writer has information which seems to prove the existence of a belt of greenstone between the iron formation and the Lower Huronian sediments along the entire north side of the trough. In the Savoy property, at the second and third levels, the contact of the slate and the greenstone was found. It was quite sharp and distinct, although, as stated above, no conglomerate could be found. The conglomerate may never have been deposited at this point and such is very liable to have been the case. The greenstone was very much altered but microscopic examination seemed to leave very little doubt as to its original character. The slates had a characteristic cleavage and contained many small seams and grains of quartz. They were very fine grained and also contained many veinlets of impregnated calcium carbonate.

The Sibley shaft was sunk in a much altered greenstone, and drifts driven north from the 10th level of the Zenith mine were stopped in greenstone. Outcrops lying a few paces west of the center of Section 27-63-12 were, upon examination, found to be greenstone. It is therefore very evident that the greenstone belt lying north of the Chandler-Pioneer deposit continues east along the trough's entire north side.

*The Ely Trough—(General)*—The lenticular body of iron formation and its including walls of greenstone has been termed the Ely trough. It has a northeast-southwest trend which is parallel to the longitudinal axis of the Vermilion range. Longitudinally and transversely its structure is synclinal. Transverse sections show that it is characteristically

(a) Geolgogy sheet XIII, the Vermilion iron bearing district, J. Morgan Clements.

U shaped at some points. This is especially true of its western portion where the Chandler and Pioneer deposits are located. Here in places the bottom of the trough has been reached showing that greenstone forms the impervious basement.

To the east, in the Zenith, Sibley and Savoy mines the greenstone walls and included iron formation dip at a high angle. Both east and west ends of the trough are canoe shaped, the west end pitching east and the east end pitching west. At the Zenith, and about midway in the trough is an anticline, subordinate in nature. This anticline separates the Zenith ore deposit into two portions, one upon either limb. It also has separated the trough longitudinally into two great synclines, one between the Pioneer and Zenith, the other between the Zenith and Savoy.

Following Van Hise's theory, the axial planes of folds dip toward the forces producing them. The longitudinal folding of the Ely trough has therefore been caused by forces acting in a northwest-southwest direction. The intensity of the folding has been greater at the east end of the trough than at any other point.

The major and minor folding has been caused by forces acting at an angle with one another. Thus the secondary fold at the Zenith has undoubtedly been produced by these forces working in conjunction.

The longitudinal folding has developed cleavage in a direction parallel to the dip. This secondary structure is present to a great extent in both the slates and greenstones.

The Knife slates at the east end of the trough have apparently undergone most of the main structural changes affecting the older iron formation and greenstone. The iron formation has been mashed and broken and recemented with silica, hematite and iron carbonate. This is more noticeable in the Savoy and Sibley mines than at any other point of the trough.

The ores of the district lie at or near the bottom of the trough and upon the impervious basement of Ely greenstone, At only one point of the trough did the ore reach the surface, This occurred at the west end of the Chandler deposit. As a result of the trough's steep pitch to the east the ore body rapidly passed under the capping of jaspilite. All of the ore bodies of the trough lie beneath a jaspilite capping. In the upper portions of the trough and near the surface the jaspilite lies in contact with the greenstone. Lower down the ore is in direct contact with the greenstone.

Horses of greenstone are present in the ore bodies in a number of cases. These greenstone projections can, in almost every case, be traced into the footwall showing that their presence in the ore body is due to infolding. This is true for the west end of the trough only. At the east end inter-bedding seems to explain the presence of greenstone horses in the ore bodies.

At the east end of the area, while the formations form a pitching trough, the structural conditions have been formed in a different manner. This will be explained under the head of "Relations of the Soudan Formation to the Ely Greenstone."

### GEOLOGY OF INDIVIDUAL DEPOSITS OF THE TROUGH.

*Chandler-Pioneer Ore Deposit.*—The Chandler-Pioneer ore body is the largest yet developed in the area. It occurs at the bottom and comes part way up the sides of the eastward pitching trough. The enclosing walls are of greenstone, as is also the impervious basement upon which the ore lies. The rocks have been closely folded and as a result many irregularities in structure occur.

The north and south walls at one point in the Chandler dip at an angle of about 70 degrees to the north. Further east, in the same ore body, the south wall becomes more inclined while the north wall dips at a high angle to the south.

In many cases the intense folding has caused a reversal of dip of the walls. These points are illustrated in sections A, B, C, D, and E, F. These sections also show an increased depth to the trough as it pitches east. The longitudinal section illustrates this fact very clearly.

One especially interesting feature is the presence of a number of subordinate rolls at or near the bottom and sides of the trough. In all cases they are protubrances from the enclosing walls of greenstone. On section A-B the subordinate anticline is very prominent. This has separated from the ore body a small lens of ore. Infolding probably explains the occurrence of this isolated vein. Where examined underground it lay between two walls of greenstone, and was very compact in structure. No paint rock was present, the ore being in direct contact with the greenstone. This subordinate roll in the Chandler can be traced into the Pioneer workings where it has become of great importance. Here it entirely separates a small ore body from the main body. It may eventually cut out this ore body entirely as did a similar roll in the upper workings, and connect with the south footwall. (Section C-D.)

The north and south walls of the trough are of greenstone altered to soap rock or paint rock. The soap rock is the altered equivalent of the greenstone and grades into it in most every case. At the contact of the ore and the soap rock the soap rock is very shistose and shows slicken sides, while the ore is generally much broken. There is at many points along the contact a considerable thickness of brecciated matter. This consists of fragments of paint rock included in the ore. The jaspilite being a much more resistant rock, did not break and mash as readily as the greenstone. This, together with the slicken sides, indicates that great movements have taken place at the contact of the two formations. The plane of contact has afforded ready access to descending waters. As a result the greenstone has altered to soap rock, and iron oxide has been infiltrated giving the soap rock a characteristic red color.

Lying next to the soap rock is the ore; above the ore is the capping of jaspilite. The contact of the ore and jaspilite is very irregular. Jasper bunches project into the ore body at many points. Both ore and jasper have been much broken and mashed. This is due to the forces which produced the folding and formed the trough in which the ore lies.

The banding in the ore is very similar to that of the jasper, in fact there is a gradual change from merchantable ore to lean ore and from lean ore to jasper. In general the brecciated ore has been recemented by iron oxide and to all appearances is massive in structure.

At a number of points, before the jasper capping is reached, a considerable thickness of paint rock is encountered. The origin of this paint rock is doubtful. Upon the south and east sides of the trough the paint rock, or soap rock, is clearly traceable into the footwall.

While this explains the presence of paint rock for this portion of the contact, it does not account for the isolated bunches nearer the center of the deposit and completely cut off from either wall. If these bunches can be traced into the footwall, as increased depth is reached, then their origin is clear. In a number of instances seams of paint rock varying from a few feet up to twenty or more have been encountered in the ore body itself and entirely removed from the walls of the trough. It has been proven for the district in general that there are subordinate amounts of interbedded slates in the iron formation. These slates were evidently originally detrital mud. The isolated paint rock seams may have originally been these slates.

*Zenith Ore Deposit.*—The Zenith ore body lies between two walls of greenstone dipping at an angle of about 75 degrees to the north. The north and south walls are approximately parallel. More intense folding has taken place at this point in the trough than at the west end—in the Chandler-Pioneer properties.

The relations of the greenstone, paint rock, ore, and jasper are, in general, similar to those at other points of the area.

There are two separate ore bodies in the Zenith mine. These ore bodies are separated by an anticline which has had considerable influence upon their deposition. The axis of this crossfold lies approximately in an east-west direction. The ore

bodies appear to be upon either limb. The first ore body found in the Zenith was that lying upon the south limb of the anticline. As depth was reached this ore body was found to follow down this limb until at the 10th level, it is some 300 feet west of where it was first found in the old upper workings.

Development work has shown that this anticline has a core of greenstone which has altered to soap rock upon either limb and upon its crest. The jaspilite capping lies immediately upon the crest.

The main ore body of the Zenith was located by means of diamond drills from the bottom levels near the shaft. This ore body lies upon the north limb of the anticline mentioned above.

Both ore bodies lie mainly upon the footwall side of the formation. The main ore body occupies the full width between walls as increased depth is reached. The ore lies higher up on the footwall than upon the hanging wall side. It is quite evident that the major circulation of descending water was upon this side of the fold, and because of this more work of concentration was accomplished. The soap rock is also much thicker upon the footwall, showing that descending waters have been unusually active at that point. The main ore body is pitching to the east under the jaspilite capping. From the 9th to the 10th levels it has gained nearly 500 feet. As to whether it will eventually connect with the Sibley deposit we are not certain. Everything points to that conclusion, however. This, of course, does not take into account the possible occurrence of other cross folds which may cut out the ore body and prevent them from connecting. It was possible to separate a zone of altered greenstone lying between the unaltered greenstone and the soap rock. This merely represents an intermediate stage in the process of alteration of the greenstone.

*Sibley-Savoy Ore Deposit.*—The Sibley-Savoy ore deposit lies in a westward pitching trough. The enclosing walls are of greenstone which dip at a high angle to the south.

The ore lies mainly upon the footwall side, but with increased depth occupies the full width between the walls. The ore body itself is lenticular in shape, being about 150 feet wide in places and narrowing to nothing at the east end. At this point the foot and hanging walls come together like a V and the ore body pinches out. The main ore body, and that from which the most ore has been mined, lies upon the Savoy side, but with increased depth the greater ore body will no doubt be found upon the Sibley property. The Sibley ore body is rapidly gaining to the west under the heavy capping of jaspilite.

In the Savoy the Knife slates have been encountered. No, 2 shaft was sunk mainly in slate, and drifts driven from this shaft passed through a considerable thickness of them. The slates dip to the south at a higher angle. They have been metamorphosed so that the original bedding planes have been destroyed. The footwall of greenstone lies in a narrow belt between the slates and the ore body. At the contact of the slates and the greenstone no conglomerate could be found. The conglomerate has no doubt been destroyed by the shearing which took place at the contact. The greenstone is much altered, its original character being hard to recognize. A considerable thickness of paint rock lies between the greenstone and the ore, and especially at the west end of the trough. At the east end, in the upper workings, rich red paint rock was also present but as depth has been reached this has disappeared. At the extreme east end of the Savoy the ore lies in direct contact with the greenstone. The greenstone is much altered, but the absence of red paint rock is very noticeable.

In the mines of this district red paint rock, or soap rock highly impregnated with iron, is considered to be a very favorable sign for ore. The absence of this at the east end of the Savoy merely emphasizes the barrenness of the formation at this point of the deposit.

The ore in the Savoy is harder and more compact than in the Sibley. Pillars fifteen feet square stand without crushing, while in the Sibley a pillar of that size would stand for but a short time.

As stated above, this ore body, and especially in the Savoy mine, is pitching to the south at a high angle. Facts seem to point to a rapid flattening of this angle and approaching nearer 45 degrees. In the bottom of the Savoy mine is a long narrow lens of greenstone and paint rock. This seam, or lens, first appeared in the second level workings. It seemed to be a projection from the footwall. As depth was reached it grew to be of more importance, until upon the 3rd level it has completely divided the ore body into two portions.

Future development may show it connecting with the footwall, or it may continue as a narrow sheet in the ore body. Facts seem to point to it connecting with the footwall throughout the entire length.

At the contact of the ore with the hanging wall in the Sibley mine the banding of the ore is approximately parallel to the dip of the soap rock. At this point the soap rock and ore are intimately associated, there being a considerable amount of brecciated matter composed of pieces of ore, jasper and soap rock. In some places the ore lies against a clean face of soap rock, its bedding planes being parallel to the dip of the soap rock hanging wall. The soap rock always shows slicken sides, an indication of the great movements that have taken place at these points.

In the Savoy and Sibley deposit a large amount of iron carbonate is found. This occurs as yellow and reddish crystals in the cavities and seams in the ore. It has in many cases recemented the brecciated ore as the old fracture planes may be easily seen.

This iron carbonate is clearly of secondary origin.

### CONCENTRATION OF THE IRON ORES.

It is very evident from a study of the sections through the Ely trough that the contact of the iron formation and the greenstone has very strongly influenced the concentration of the ores. These planes of weakness were the means by which the descending waters reached the bottom of the trough.

The formation of the ore bodies as a result has been dependent upon this means of ready access to the iron formation. Where the descending waters converged and met at the bottom of the trough in the Chandler-Pioneer deposit there the largest ore bodies were found. This is true to within certain limits, there being in a number of cases a pinching of the walls with an enlargement of the ore body below.

Abundant circulation of water for a long period of time, together with ideal structural conditions, has made the concentration of the ores in their present position a possibility. Prof. C. R. Van Hise has discussed at some length the process of concentration by means of which these, and other similar ore deposits, have been formed. His ideas, as summarized by J. Morgan Clements in monograph XLV, U. S. G. S., explains very clearly the origin of the ores of the Vermilion district. This district, and especially the Ely trough area, affords a perfect confirmation of the theory of the occurrence of iron ore deposits as stated by Prof. Van Hise. Here we have the pitching U shaped trough bottomed by a practically impervious rock. This is especially true of the Chandler-Pioneer ore body. With some modifications, the same conditions exist in the Sibley-Savoy deposit.

The summary of Prof. Van Hise's theory from monograph XLV, is as follows:

"The source of the iron for the enrichment of the ores is believed to have been mainly iron carbonate. Meteoric waters are charged with carbonate. As they enter the soil they would be dispersed through innumerable minute openings. The waters which early in their journey come into contact with iron carbonate would have their oxygen abstracted. Such waters would be likely to be those following circuitous routes. The deoxidation of the waters by the iron carbonate would produce ferruginous slates and ferruginous cherts. In this alteration the carbon dioxide would be liberated, and would join the descending waters. Thus carbonated waters free from oxygen would be produced. Such waters are capable of taking a considerable amount of iron carbonate and some iron silicate into solution. Large quantities of these solutions would be converged upon the sides or at the bottom of the pitching troughs, or in other places where there were trunk channels for water circulation.

After an iron bearing formation was exposed to descending waters for a considerable time, a large part of the iron carbonate adjacent to the surface would be transformed to ferruginous slates and ferruginous cherts. This change would take place most extensively where waters were abundant and a somewhat direct course led to the trunk channels. After this process was completed at such places, the waters now following this direct route would pass only through the ferruginous slates and ferruginous cherts and would reach the trunk channels charged with oxygen. There the solutions bearing iron carbonate and those bearing oxygen would be commingled. Iron sesquioxide would be precipitated. Therefore the iron oxide of an ore body consists in part of iron compounds originally deposited in situ and in part of iron brought in by underground waters. The material deposited in situ may have been originally detrital iron oxide or it may have been derived from iron carbonate, iron sulphide, or iron silicate, which was oxidized in place, or from two or all of these sources. It has been assumed that the part brought in by underground waters was mainly transported as carbonate, although a portion may have been transported in some other form. Of the two sources of iron ores, the original material and that added by underground water, the latter is upon the average probably more abundant. But in some exceptional cases, where there is a large amount of detrital iron oxide, the material added by underground waters may be subordinate. However, in all cases it may be said that were it not for the secondary enrichment by underground waters, through the addition of iron oxide, the material would not be iron ore. The evidence of this lies in the fact that the ore bodies are universally confined to the places where underground waters have been converged into trunk channels.

The ore deposits contain upon the average a less quantity of silica than does the average of the iron-bearing formations. It follows therefore that silica must have been dissolved. This doubtless was largely the work of the great volume of water converged into the trunk channels. It has been seen that the waters which carried iron carbonate to the ore deposits were carbonated. The precipitation of iron oxide from carbonate liberated more carbon dioxide, so that the waters were very heavily charged, with carbonic acid. In some of the districts basic igneous rocks occur within the iron ore deposits or as basements to them. In all such cases these basic rocks are found to have lost a large part or all of their alkalies. These must have passed into the solutions. Hence the waters moving along the trunk channels would in some cases contain alkalies besides being rich in carbon dioxide. It is well known that such solutions are capable of dissolving silica. Therefore the conditions which result in the precipitation of iron oxide also furnish conditions favorable to the solution of the silica. Silica is thus largely dissolved from the ore bodies and transported elsewhere. The removal of the silica is ordinarily only less important in the development of the ores than in the addition of the iron. In many cases the abstraction of the silica proceeded further than the deposition of the iron oxide, thus making the rocks very porous and further rendering the conditions favorable for abundant circulation."

In the Ely district it is quite evident that the main concentration of the ore has occurred subsequent to the formation of the main structural features of the trough.

The relations of the ore bodies to the trough are very definite in that they conform very closely to it in outline. They have evidently been deposited in their present positions after the main period of folding had been finished. However, some of the ores and most of the jaspilites are now, or have been, in a brecciated condition. It is plain that movements have taken place while they were near the surface and that considerable movement was necessary, as both ore and jaspilite are exceedingly hard when in massive state.

Prof. C. K. Leith states that where the Ogishke conglomerate is found, jasper, and not ore fragments exist, if any iron formation at all is present in the conglomerate. If iron ore had been formed in any quantity previous to the time these sediments were laid down evidence of its formation would be found in the conglomerate. This fact, together with the present relation of the ore body to the adjacent formations seems to point to a possible modification of Prof. Van Hise's theory for the concentration of the iron ores. He states that concentration of iron oxide may have occurred during the process of alteration of the iron bearing carbonate, ferrous silicate, or pyrite to ferruginous slates and cherts. This may be the case in many of the iron districts; however, it seems that the process has been slightly different in the Ely trough area. In this area the original rock was probably iron carbonate. This was altered to ferruginous cherts with very subordinate amounts of ferruginous slate. The formation then consisted almost entirely of ferruginous cherts and slates with very little if any iron ore in quantity. The Lower Huronian sediments were then laid down and subsequent folding placed the formations in their present relative positions. The fracturing of the pebbles of the Ogishke conglomerate show that extensive movements have taken place after its deposition. After this main period of folding had passed, the concentration of the iron ores was begun. Silica was leached out and the iron formation as a whole decreased largely in volume. In some cases the removal of the silica caused a slump which fractured the formation, in others the formation became porous. In the Pioneer mine the ore body has a porous structure in general, although the ore itself is hard and compact. During the process of replacement by means of which the ores were concentrated the greenstone at the contact with the iron formation was altered to soap rock and in most cases infiltrated with iron oxide.

The writer does not believe that great movements of the rocks of the trough have taken place since the formation of the ore bodies in their present relative positions. There are in many places along the contact of the iron formation and the Ely greenstone considerable amounts of fragmental material. This material consists chiefly of pieces of soap rock and ore with a matrix consisting of a mixture of both. The soap rock and the ore exist as angular fragments. As the soap rock was formed by alteration of the greenstone this alteration must have taken place while the ore bodies were being formed in their present position, for it was at that time that circulating waters were most active at the contact. If these movements tóok place after the alteration to soap rock no angular pieces would be present, as it is a very soft rock. It is therefore evident that the fragments of greenstone were detached from the wall and placed in their present position before they had altered to soap rock. Where we find the ore lying against the soap rock without fragmental matter, although the soap rock shows slicken sides, it is evident that the movements causing the slicken sides occurred previous to the alteration of the soap rock, and, therefore, also before the main concentration of the ore. If the waters were descending, as seems to be now proven in general, alteration was first begun at the contact of the iron formation and the greenstone. As the great thickness of soap rock on the hanging and footwall sides of the trough must have been formed contemporaneous with the ore it is evident that any movements tending to strain and fracture the ore would have caused a different state of affairs than we now find at the contact. In most cases the banding and fracturing of the ore is similar to that of the jaspilite.

It seems evident that the main fracturing of the ore formation occurred previous to the formation of the ore bodies in their present positions for they now rest in places most favorable for the circulation of underground waters. Any great movements would have changed these positions. The ores have been formed by a process of replacement and they retain, as a whole, practically the same structure as that existing in the jaspilite at present.

The iron formation and the enclosing greenstones were at one time deeply buried. That the iron formation was in the zone of flowage is evidenced by the intricate folding it has undergone without a sign of fracture. From the zone of flowage the rocks were elevated to the zone of fracture for ore and jasper; here they were subjected to further movements and were mashed and broken. This brecciation increased the openings in the iron formation and thus afforded an easier access to circulating waters. As a result infiltration and recementation took place and the brecciated ores are now cemented by hematite, calcite and siderite.

The iron ores are replacement deposits. Wherever actual contacts with the jaspilite were observed the ore graded into it. The ore in the Sibley and Zenith mines has the mashed, banded structure so noticeable in the iron formation. This is true to a greater or less extent in the remaining mines of the district. Thus it is clear that the rock from which the ore was derived by a process of replacement was a banded rock. The original nature of this rock has been discussed above.

The time of formation of the ores has not been definitely fixed. J. Morgan Clements believes "that the process of folding was inaugurated between the Archean and Lower Huronian time," but since the present attitude of the troughs in which the main ore deposits are located was mainly produced by the folding of the Lower Huronian, the replacement certainly occurred for the most part after Lower Huronian time. Since there are no pre-Cambrian deposits later than the Lower Huronian in this part of the district, the determination of the time of the replacement process cannot be more accurately made. The process began shortly after the Lower Huronian time doubtless has continued, perhaps with interruptions, to the present time."

That the major folding of the trough occurred after Lower Huronian time is shown by the position of the Knife slates in the Savoy property (see section M-N.) Here the dip of the slate corresponds to the dip of the trough to the south.

RELATIONS OF SOUDAN FORMATIONS TO THE ELY GREENSTONES.

By far the greater portion of the Soudan formation is younger than the Ely greenstone. The exact relations of the two are fairly well determined in some instances. In some cases their relations are clearly of infolding of the iron formation in the greenstone, while in others interbedding seems to be the correct solution. At the west end of the Ely district, in the Chandler and Pioneer deposits, every fact seems to point to infolding of the iron formation rather than interbedding. Here we have the characteristic U shaped trough bottomed by an impervious basement of greenstone. The iron formation conforms in contour to the shape of the greenstone basement. Where irregularities occur in the greenstone the iron formation has shaped itself to conform to them. Actual contacts show the ore lying against a clean face of altered greenstone, at some points, at others, there is a considerable amount of fragmental matter consisting of irregular pieces of altered greenstone and ore. The soap rock shows slicken sides in nearly all cases. The presence of subordinate synclines and anticlines of greenstone at, or near, the bottom of the trough is good evidence of infolding. At the central and eastern portions of the area in the Zenith, Sibley and Savoy mines we have a very different state of affairs. The greenstone walls are approximately parallel and the iron formation between them is very narrow. Upon the north side of the trough, at the Savoy, we have a narrow belt of greenstone lying between the Knife slates and the iron formation. All of the formations dip at a high angle to the south.

About 1,300 feet south of No. 2 shaft, Savoy, a vertical drill hole passed through 85 feet of ore at a depth of 1,253 feet. Midway in this ore was a seam of altered greenstone 13 feet thick. This ore body lying so far south of the Savoy deposit, and buried under such an enormous thickness of greenstone, seems to indicate that it has been interbedded rather than infolded. The presence of the seams of altered greenstone in the ore is good evidence, in itself, of interbedding.

In the Zenith mine, drilling done to a depth of 700 feet below the 10th level also reveals some startling facts. The iron formation and greenstone form a fold shaped like the letter J. The formations dip to the north at a high angle until, at a depth of 400 feet below the 10th level, they turn back upon themselves, rise toward the north to a point 70 feet below the 10h level and 400 feet north of where the hanging wall is encountered on that level. To explain this occurrence by infolding must necessarily involve a very complicated series of movements of the formations. As in the Savoy, the facts seem to point to interbedding rather than to infolding. In both deposits, long seams of altered greenstone are encountered in the ore body. In the Savoy especially we have a seam that has divided the ore body into a north and south lense. This, as in the drill hole mentioned above, is evidence of interbedding. One will ask how it is possible that infolding could have occurred at one end of the trough and interbedding at the other, it all being in a continuous iron formation. Such an occurrence could easily occur without violating geological principles. It is evident that after the interbedding of the iron formation at the east end of the area that great movements took place. This is evident because of the position of the slates and their dip to the south. It is certain that nowhere in the Lake Superior region has there been folding that will enable as to explain the relations of the different formations at the east end of the Ely trough.

As stated by Clements in the Vermilion monograph, he has found small seams of greenstone interbedded with iron formation at different points in the district. These greenstones represent flows contemporaneous with the formation of the rocks of the iron formation. That this has occurred on a much larger scale in the Ely district is very probable. While the iron formation sediments were being laid down, outpouring of lavas may have occurred simultaneously, and as a result we have the two formations intermingled. Both may then have been covered by the later Lower Huronian sediments.

## INFLUENCE OF TOPOGRAPHY.

While topographic conditions undoubtedly influenced to a great extent the deposition of the ores of the trough, yet their part as evidenced by present conditions cannot be readily determined. The Ely trough lies below an ampitheatre of greenstone on the south and west and a portion of the north side. Glacial drift covers the greenstone to a large extent. The long slope south of the trough rises to a point 100 feet above its edges, the area draining towards the trough approximates three square miles. Meteoric waters falling in this area descend to the greenstone and are either held there or pass down the long slope across the trough and into Long lake. Where they cross the trough marked topographical depressions are noticeable. They have, in a number of points, cut through the north rim of the trough. As to what portion of the water descended and circulated through the iron formation is a question. The difference in elevation between various points of the formation is not sufficient to allow of any great head at any one point. It is certain that the waters must have circulated to a great extent in the iron formation. Shafts sunk in the south wall of greenstone encountered very subordinate amounts of water, showing that descending waters do not circulate in the greenstone in large quantities at great depth. As some of the water certainly descends and circulates in the trough, the question arises as to where it eventually goes. If the trough has an impervious bottom throughout its entire length, as seems to be the case, the waters must be held at the low point. However, the basement greenstone is not wholly impervious, and it is certain that circulation must have extended down to the zone of flowage, where it could not go further. There is a possibility of there being an opening enabling the waters to escape somewhere along the north side of the trough. However, Long lake is but a very little below the trough as a whole, and any opening of this kind would certainly cause more water to be encountered in the lower workings of the different properties. That the waters in most cases must again have reached the surface at some point is certain.

Conditions in pre-glacial and glacial times were very different from those existing today, and it is certain that the concentration of the ore was well along before those periods.

A study of the topography of the area does not enable one to form an opinion as to the possible depth or the effect of circulating waters.

### PRESENT CIRCULATION OF UNDERGROUND WATERS.

Circulation of underground waters at all points observed in the Ely trough is downward. The Pioneer mine, whose workings are below those of the Chandler, to the west, is pumping practically all the water of that deposit. This does not average much more than 400 gallons per minute. At the east of the trough we have a somewhat similar state of affairs. The Sibley and Savoy bottom workings are about upon a level. The east end of the Savoy, and especially near the converging walls of greenstone is very wet. This indicates that the main circulation of water is now down the end of the canoe shaped trough. The Sibley shaft is, however, very wet compared with the Savoy, and all the water from both properties is pumped through this shaft. At the Zenith less water is being pumped than at the Pioneer, this is also true of the Sibley. The Zenith, however, is handling more water than the Sibley. When the ore body is tapped from Zenith No. 2 shaft a much larger flow than now encountered in No. 1 shaft is expected. In all of the properties the main circulation of water is upon the footwall side of the formation. It is evident from the above facts that the flowage of underground water at present is very small compared with what must have circulated at one time.

We may assume, however, that the present day circulation in these properties is in practically the same channels as during the formation of the ore body.

### EXPLORATION.

The only productive deposits on the Vermilion range are at Tower and Ely. In both cases the ore bodies reached the surface at some point. For some years many thousands of dollars have been spent in exploring the different belts of iron formation, without satisfactory results. In some cases the work has been done in a very systematic manner; in others, without regard to existing geological conditions. There still remain numerous exposures of iron formation that have not been systematically explored. It may be said that the Vermilion range is possibly the most difficult to explore of any of the iron bearing districts in the Lake Superior region.

From a study of the deposits of the Ely trough it is possible to arrive at a few conclusions regarding exploration. In the first place the iron formation and adjacent formations should be mapped in a careful manner. Detail maps of favorable areas should be made showing all outcrops, with their strikes and dip. When possible, a careful magnetic survey should be made, showing the lines of maximum variation. This sometimes enables the iron formation to be traced under the heavy covering of glacial drift encountered at so many points. As is plainly evident, the iron formation should be the locality for exploration, where of considerable width, it is most favorable for exploration, although the smaller exposures should not be wholly neglected.

As will be seen from plate I, the iron formation is about 1,400 feet wide at one point in the Ely trough, yet it narrows to scarcely 150 feet at its east end. Good deposits of ore were found at the narrowest point of the formation. As is evident from the cross-sections of this area, the ore bodies lie in pitching troughs with impervious basements. Where the ends of the formation can be found they should be carefully examined for evidences of such structure. At only one point in the Ely trough did the ore reach the surface. This occurred at the west end of the Chandler mine. The remaining deposits of the area were found beneath a heavy capping of jaspilite, varying from 300 to 800 feet in thickness. It is, therefore, not probable that all of the ore deposits yet to be discovered will be found at, or near the surface.

In the early days considerable drilling was done at the narrow east end of the Ely trough. Low angle drill holes were put down. These holes, in most cases, were located on either the foot or hanging wall side and passed from foot to hanging through jaspilite. As is seen from the cross-section, they cut the formation above the main ore body in every instance. It is true that some ore was encountered, but it was mainly small bunches in jaspilite, and not the main ore body. It is therefore evident that future exploration should be done by means of deep high angle holes, as the ore bodies in almost all cases lie at considerable depth. Low angle holes are drilled with considerable difficulty, owing to their liability to cave readily. To ream a hole and case it is very expensive. In most cases vertical holes can be sunk with far better success.

The Savoy main ore body was discovered by means of a vertical drill hole, and its extension to the south was also located in the same manner.

Where possible, every means should be used to determine the dip of the formation. In case sufficient money is available, it would pay to determine this by means of a few low angle holes. The holes should be carefully platted and the cores saved. As shown by the cross-sections of the trough, a reversal of dip of the formation at any one point, is quite improbable. In case the dip can be fairly well determined, the location of drill holes can be made to a much better advantage. If this is done, the cheapest plan to follow is to sink a vertical, or steeply inclined hole upon the hanging wall of the formation. Greenstone is drilled at a much cheaper rate than jaspilite, thus great depth may be secured at the lowest possible cost. The explorer should aim to prove the formation at considerable depth, as it is evident that the ore bodies lie at or near the bottom of the troughs. Some explorers claim that steeply inclined drill holes are liable to follow a seam of ore, and thus give inaccurate information.

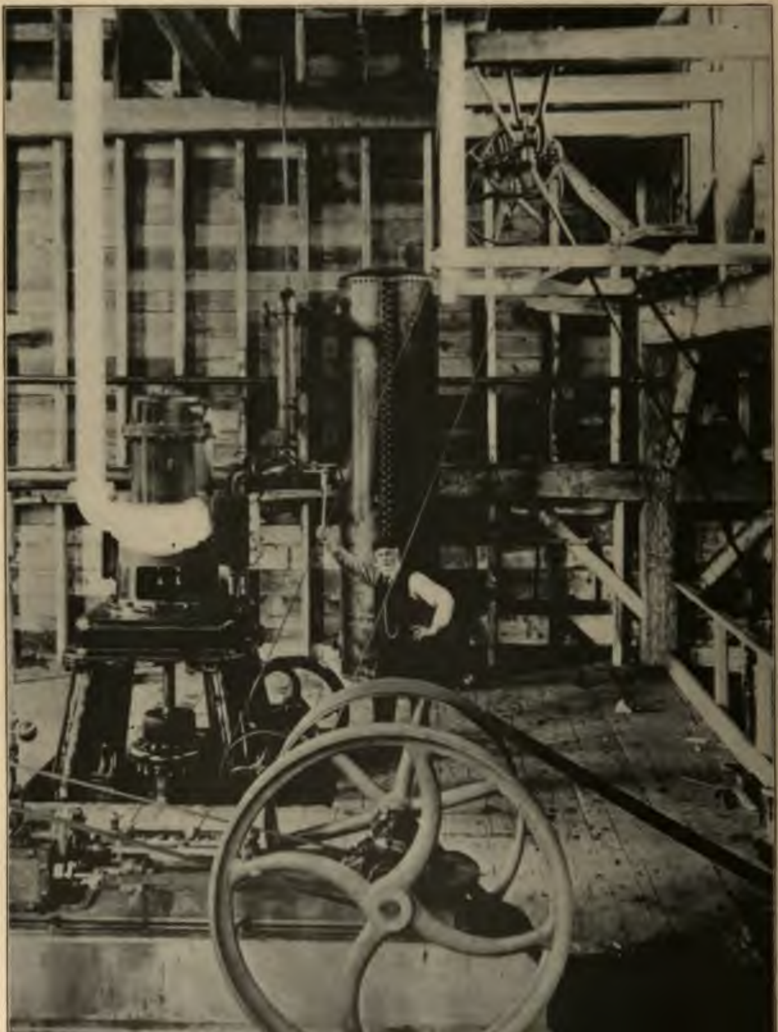
As the iron formation of the Vermilion Range has been folded in a most intricate manner, that a drill hole should encounter a continuous seam of ore is highly improbable.

At points where the iron formation appears to lie in a normal syncline it is evident that high angle or vertical holes would have to be drilled in jaspilite at great expense. A deep low angle hole located either at one side or the other of the trough would probably be the cheapest. As seen from plate II, a vertical hole midway between the north and south limits of the iron formation of the Pioneer deposit would certainly have located the ore body.

In conclusion it is well to state that all exploring should be done in a systematic manner. The records of the drilling should be carefully kept, and typical cores saved. Structural sections should be made from the surface information and from the drill records. This, in many cases, would enable the explorer to plan his future exploring and developing to a much better advantage.

VICTORIA HYDRAULIC COMPRESSOR.

Air Discharge End, Showing Blow-Off (Long Bended Pipe) and Feed to Air Main (in Angle of Roof and Far Wall). The Water Flows Through Tunnel Where Men Are Standing and Thence Through Discharge Shaft to Surface.



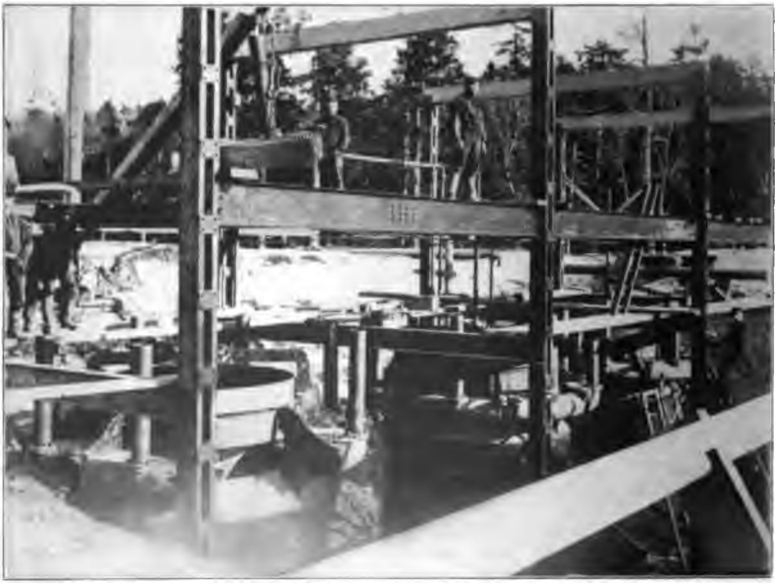
VICTORIA HYDRAULIC COMPRESSOR.

Stamp Head Operating With Compressed Air, Showing Coating of Frost on Exhaust Pipe in August.

VICTORIA HYDRAULIC COMPRESSOR.

Blow-Off in Operation, Discharging Surplus Air, Mingled With Water, Height of 350 Feet.

VICTORIA HYDRAULIC COMPRESSOR.
Lower End, Showing Deflectors. (Water Line Is One Foot Above Cylinder Extension of Shafts).



VICTORIA HYDRAULIC COMPRESSOR.
Upper End, Showing Air Entraining Tubes.

# FIVE YEARS OF PROGRESS IN THE LAKE SUPERIOR COPPER COUNTRY.

By J. F. Jackson, Houghton, Mich.

The last copper country meeting of the Lake Superior Mining Institute was held at Houghton in the early part of March, 1901. At that time the exploration and development of new properties and the increase in production of old properties, due to the better demand for copper had gained considerable impetus. Out of the number of new mines floated during the boom, a goodly percentage have developed into established paying properties. The annual production of copper has grown from 139,000,000 to 240,000,000 pounds.

The duty of describing the principal features of five years of engineering progress in this district has developed upon the writer, with the probability that little more than a catalogue of the more important achievements will be presented.

Let us begin geographically rather than chronologically and work from north to south. New blood in the shape of hard cash is going into Keweenaw county, with the result that a new railroad is being constructed from Calumet to the point, and extensive explorations are being conducted by the Keweenaw Copper Co., and the Calumet & Hecla interests.

The Mohawk has developed into a dividend payer with an enviable record of low mining costs. They have under construction a new system of disposing of tailing sands, whereby the stamp sands are separated from the water and carried out several hundred feet on a horizontal conveyor belt. The sand is then dumped back into the flowing water and distributed into the lake. Launders with steep grades and high velocities to carry sand and water combined are thus dispensed with.

The launder carrying water alone runs out at a slope of perhaps one foot in five hundred. The 100 tons of sand and 3,000 tons of water per hour are therefore delivered for deposit several hundred feet further out from the mill with the expenditure of the very small amount of horse-power necessary to operate the conveyor belt. The resultant economy of operation should be very much greater than could possibly be obtained by the use of sand wheels or pumps to accomplish the same purpose.

Adjoining the Mohawk is the Ahmeek noted as the first to use concrete stringers for skip tracks. In this construction, parallel longitudinal stringers of solid concrete are built, directly on the footwall. Their width on top is about 12 inches. Their depth runs from 14 inches to three feet, or more, varying with the irregularities in the footwall. Rails are fastened directly to the top of concrete at three feet intervals, with bolts and clips. Needless to say the grade and alignment of the track are perfect and will always remain so. No excuses for extra cost have to be offered because this fire-proof permanent construction actually costs less than the old standard timber work with its short and troublesome life.

The new central power plant consisting of boiler house, compressor, two hoists, engine and dynamo, is nearly completed, and electricity will be used for the distribution of power to all small auxiliaries in and about the mine. This plant is located midway between the two shafts. An interesting variation from the ordinary rock house construction has been worked out for this location. Copper rock from both shafts will be mechanically trammed on elevated trestles to a central crushing plant. Here the rock is first screened to three sizes. The intermediate and large sizes are fed through chutes to crushers. The fine and crushed rock all run to one hopper, from which they are carried by an inclined link belt elevator of large capacity to the top of a circular storage bin of 1,500 tons capacity, from which rock is forwarded to stamp mill. The three rock chutes of the Calumet & Hecla type in bin bottom will all be controlled from one point by a bank of levers.

Next in line is the Allouez, which made the remarkable record of sinking a large shaft 1,400 feet at the rate of 100 feet per month. This shaft is sunk at 80 degrees, to its junction with the lode, at which point it turns and follows the lode at an inclination of 40 degrees. This is the only example of the kind in the county and it has been very successful in operation.

At the Kearsarge of the Osceola, new and improved skips have been installed and old timbering is being replaced by rock fills and concrete stringers on the footwall.

The Wolverine has recently made a record by maintaining its regular production for a period of three months from one shaft, while its rockhouse at No. 3 shaft, which had burned down was being replaced by a steel one. The Wolverine is credited with producing a pound of copper cheaper than any other mine at the Lake.

The Centennial has two shafts on the Kearsarge lode. They are close together at the surface but diverge at quite an angle as they follow the lode. No. 2 shaft has a lateral curve of 15 degrees at a point from the surface. This shaft is being supplied with a circular steel rock house of new type. It has a circular rock bin 36 feet in diameter and 34 feet high, resting an a concrete foundation 14 feet high. The working floor accommodating crushers, grizzlies, etc., is 36 feet square and is carried directly by the circular bin and some additional columns. This is an economical plan, fire-proof, has large bin capacity and should be very satisfactory in every way.

The Calumet & Hecla is developing the Kearsarge lode extensively at several points. All new shafts have been "timbered" with concrete from the surface, to the ledge, a proceeding which is worthy of extensive imitation. Kimberley skips of large capacity are in use at the Whiting shaft. From an engineering point of view, probably their most important departure from previous practice has been the installation of a large central electrical power plant at Lake Linden. Ten thousand horsepower has already been provided. Alternating three phase current at 13,200 volts is carried by double pole lines to a Calumet transformer sub-station from where it is distributed for use to shops, rock houses and other points at a pressure of 2,300 volts. Current from the same plant is also used in the stamp mills.

At the Tamarack, a fire which broke out several months ago and probably continues to smoulder, has so filled the mine with gas as to entirely cut off production from No. 1 and No. 2 shafts. No new construction of particular interest has been done since the completion of No. 5 shaft, the sinking of which was described in a valuable paper presented at the last Houghton meeting.

The plain facts regarding the behavior of rock under great pressure and other conditions which have to be met in mining the conglomerate at great depth, should some day be given to the public by a competent observer and writer. Many theories based on lack of full knowledge of the actual conditions would surely be shattered by such a statement.

Tamarack No. 3 now has the distinction of being the deepest vertical shaft in the world. It has reached a depth of 5,200 feet. Sinking is still under way.

Adjoining the old Osceola, is the Tecumseh, which is sinking in very promising ground on the Kearsarge lode.

The Rhode Island is doing diamond drill work in search of the same popular formation.

The Franklin is doing extensive exploration work besides making a regular and increasing product. A circular steel rock house is under contract.

The Arcadian is conducting exploration work in promising looking ground. The work of rejuvenating the old Hancock mine is just being undertaken.

The Mesnard shaft of the Quincy has the first re-inforced concrete stack to be built in the copper country. It is an interesting construction. The Quincy, besides being distinguished as the "Old Reliable" dividend payer has the eminent distinction of being the first to produce genuine man-made earthquakes. Now that their cause is understood, the mystery and fear have been dispelled and we feel rather proud of this, the latest great achievement of man.

The Atlantic is temporarily out of business, due to the caving in of the ground into old stopes near the surface. This mishap has forcibly brought to our attention the fact that hanging walls sometimes hang very heavy indeed. Given a vertical depth of some 2,000 or 4,000 feet, and assuming rock to weigh 140 pounds per cubic foot, what is the uniform weight per square foot on the underlying stratum of rock? What will be the pressure on a space 100'x100'? Assume that 80 per cent. of the vein is stoped out, what will be the pressure per square foot on the 20 per cent. of pillars, etc., that remain? The solution of the above simple arithmetical problems will result in some startling figures. It is, of course, understood that whatever timbering is done at great depth only serves to keep open the active stopes temporarily.

On the south side, the Lake, the Isle Royale and Superior are doing extensive exploratory work.

At the Baltic, which, with the Trimountain and Champion now constitute the mining division of the Copper Range Consolidated, the vein stands at about 70° and the filling system is used, so that the hanging wall can give no trouble. The Baltic has just put into service a new rock house at No. 2 shaft having a system of bins designed to handle rock to crushers without shoveling. The idea is a good one. The Champion mine's new air compressor with quadruple steam cylinders, holds the world's record for economy in steam consumption. The engine was designed by Nordberg to use steam at 300 pounds pressure. So far, only 250 pounds pressure have been available, but tests show a duty of something like 194,930,000 foot pounds per million heat units. With full boiler pressure the result would doubtless have been a duty at least 200,000,000 foot pounds. The first figures are about nine per cent. better than its nearest competitor.

A very interesting example of shaft sinking is under way on the Globe lands which are under option to the Copper Range Consolidated. This shaft 16'x24' was sunk as a drop shaft a distance of 140 feet. A second shaft was then started inside the large one having a shoe or shield constructed of United States steel sheet piling about eight feet long. To each piece of sheet piling near the middle, was riveted a cast bracket projecting inwardly. These brackets carry a heavy timber framework which serves to keep this shoe in shape, and also to support the several hydraulic jacks of a hundred tons capacity each, which are used to force the shoe downward. In the case of a "boil" of sand or a heavy flow of water from any particular point, in the circumference of the shoe one or more of the sections of sheet piling drops down and cuts off the flow. The upper end of the sheet piling forms an apron within which solid timbering is done. The shaft has now reached a depth of about 180 feet in water bearing sand and gravel. There is every promise of successfully reaching the ledge, which lies at a probable depth of 40 feet below the present bottom of shaft.

The Challenge, King Philip, Wyandotte and Lake are under exploration. The Winona is nearing production and has under construction a new rock house with improved methods of screening and crushing rock, which will practically eliminate all shoveling.

Operations on a constantly enlarged scale are being conducted by the Mass and the Adventure mines.

Probably the most notable achievement in an engineering way within the last few years has been the successful installation of the great hydraulic air compressor plant at the Victoria mine on a branch of the Ontonagon river. This mine is located across the deep valley of the Ontonagon river several miles from Rockland, the nearest railroad station, so that the problem of building a railroad branch or hauling fuel by team was a serious one. After careful investigation it was determined to make use of the power supplied by nature in the shape of falling water. A head of 70 feet is utilized. Water from the canal and forebay is let into the tops of vertical cylinders. At the same time globules of air are admitted into the falling water through a large number of small pipes which project into it. The water and entrained globules of air then flow down vertical pipes to a total depth of 334 feet to a horizontal chamber 400 feet in length. During the passage of water through the horizontal chamber, the entrained globules of air now at a pressure of 110 pounds per square inch due to the hydrostatic depth, rise to the top of the vaulted chamber which is cut in the solid rock and from where it is drawn for use through pipes leading to the surface. The tail water leaves the chamber through an inclined shaft rising 260 feet to the surface. In this whole arrangement there is naturally no moving machinery to get out of order so that practically no attendance is required. The compressed air is at the temperature of the river water so that there are no great temperature losses in conducting it about the location. All machinery of stamp mill, hoisting plants, shops and drills is now run by compressed air. To Captain Hooper, now retired, is due special commendation for his courage and foresight in meeting and solving this difficult problem. Those who can spare the time should not fail to visit and inspect this interesting plant.

Quite a number of stamp mills have been built or rebuilt of steel during the last five years. At several of them the Nordberg compound head has been installed. The increased use of crushing rolls, regrinding mills and oscillating tables is noted. The Champion mill has in operaton in an experimental way a so-called graded crushing system wherein the crushing of the rock is accomplished by means of gyratory crushers, rolls, grinding machinery, etc., without the use of steam stamps. Its general purpose is to accomplish the removal of the released particles of copper at each stage of the reduction in size of the copper rock and consequently with the least possible abrasion of the metal.

A general reduction in the cost of milling a ton of rock has been made and a better saving of values effected in practically every mill in the district.

In the smelting world the important event has been the completion of the Michigan smelter, which is well constructed and is supplied with modern metallurgical and mechanical equipment for economical operation. The Calumet & Hecla smelter also has extensive improvements under way, including a large and well equipped blast furnace building.

In a general way I may say that everybody's purpose seems to have been to install the most substantial and reliable machinery and to make all construction both below and above ground of the most durable and permanent character. Steel and masonry have superseded timber as building materials.

The influence of the Michigan College of Mines is extending throughout the length and breadth of the land. Indeed, the Lake Superior mining region with its early graduates from Cornwall has always been one great school of mining, but of late I believe it is entitled to be called the world's great University of Mining, whose graduates are found all over the civilized world and which is constantly being visited by students from every corner of the earth.

Lake Superior energy and cash have also contributed tremenduously during the last five years to the upbuilding of the mining industry in Arizona, in Nevada, in Montana, in Colorado, in Utah and elsewhere. Let us pray that much of the cash at least, may come back.

Trusting this incomplete appendix to Baedeker may guide the visiting members to some extent in their tour about the country, the writer will pass the subject along to the resident members and reception committee who may be relied upon to elaborate any details which you may find of special interest. I believe that no industry and no locality of equal importance in the world of affairs can point to a semi-decade of greater or more consistent achievement in every phase of progress than the last five years in the copper country.

DISCUSSION OF MR. JACKSON'S PAPER.

MR. MACNAUGHTON: Mr. Jackson's synopsis of the work of the last five years in the copper district is very worthy of note. The mining of copper is a more detailed operation than that of iron ore, because it has to be treated at the mill, and smelted on the ground, so that if any of the iron country members want to ask any questions in detail of Mr. Jackson, he will be glad to answer them.

DR. LANE: In regard to concrete stringers for skip tracks at the Ahmeek, I notice that Mr. Jackson says the grade and alignment is going to remain perfect always. If it will remain so through some of our earthquakes it will do well.

I am not altogether sure about the earthquakes being man-made. After the Atlantic mine closed up, May 26, 1906, the tracks were buckled up, bending a 30-ft. rail to a chord of 27 feet, and I walked along that track a good ways, trying to find where that extension came from. Dr. Hubbard and I found some indication of stretching farther away, but not enough to account for all of it perhaps. I am not quite clear of that being man-made, or whether man pulled the trigger and nature furnished the gunpowder.

MR. MACNAUGHTON: I would like for one to suggest to Dr. Lane this possibility. Where openings are comparatively narrow, throughout a rather narrow district from the Mohawk mines on the north to the Copper Range mines on the south, it has occurred to me that weakening that wedge in the center may have caused it to slip down on the underlying rock.

DR. LANE: We have here an inclined basin in which you have mined, and opened this slit exactly as you say. The question is whether that gives a chance to relieve a general compression that already existed. The slit works precisely as you said, but whether there is a certain stress on the rocks before the actual strain and motion takes place, that is the question.

MR. MACNAUGHTON: We had here about a year ago a very severe earthquake, felt by some as far east as Marquette.

The like of it was never seen before in this district. It was very severe. It broke windows here at Calumet and Lake Linden. That being followed by numerous disturbances at the Quincy and Atlantic suggested the idea.

MR. DENTON: In the case of the Atlantic it seems to me that the earthquake shocks which were felt for some time before the mine finally caved in were due to the slipping and settling of the overlying beds. About ninety feet over the Atlantic lode occurs a wide conglomerate, and about 500 feet farther, another. After the final cave-in it was plainly shown that the rocks just under these conglomerates had settled below and away from them. The smooth and more or less lubricated and extensive surfaces of contact between the conglomerates and the traps favor movement along these surfaces and the Atlantic cave-in showed clearly that the movement was greatest at these places. We have tried to analyze the cave-in at the Atlantic and, as Dr. Lane says, it seems that we have lost a part of the earth. Near No. 4 shaft, where the surface shows the most disturbance, several railroad tracks which crossed the lode at right angles were buckled into the form of an "S." By measurement, joints on opposite sides of the buckles must have been brought together three or four feet. The "buckles" were all alike; that is, the bending was all in the same direction, to the south. Just under these buckles, which were close to the strike line of the lode, the turf was raised and folded with the line of the fold parallel to the strike of the lode. At first glance therefore, it would seem that three or four feet of the body of the earth had disappeared from under the turf and tracks. A part, perhaps 6 or 8 inches of the fold in the tracks is accounted for by the sliding of the tracks on the ground. This sliding is shown by the ties being uniformly displaced from their original position for some distance from the fold and this displacement was always towards the mine. Where the ties were not moved, the rails slipped through the spikes. It would seem as though the hanging rocks had been stopped suddenly in their fall and that the inertia of the tracks had carried them along the surface after the latter had come to rest. Still this inertia idea accounts for only a small part of the buckling. The greater part must have been due to the settling of the hanging rocks into the space formerly occupied by the worked out portion of the lode. This settling occurred in such a manner as to crush the pillar of vein at the surface without forming a crack or hole, In a general way the surface cracks and disturbances indicated that a round shaped mass of the hanging country had settled.

MR. JACKSON: I think, Mr. President, we may rightfully stick to that proposition, that we have man-made earthquakes up here, or have had them.

# SALT WATER IN THE LAKE MINES.

By Alfred C. Lane, State Geologist, Lansing, Mich.

(Revised from article published in Portage Lake Mining Gazette, Houghton Mich.)

I wish to call attention of the people practically engaged in the mines in the copper country to certain points which as will be seen below, may be of practical importance. I write to you because I feel that I can thus reach a public who will perhaps never see my geological reports, or if so would fail to pick out the particular facts to which I wish to call their attention.

Moreover, I may be able to gather, with the co-operation of my friends and former neighbors of the copper country, facts of material value before making any official report. The time is past when the scientific and practical man work each independently of the other and with more or less scorn of the facts gathered by, and the point of view of, the other.

I wish to suggest that it may be that the character of the waters of the copper mines has a real connection with the richest parts of the lodes. This, as will at once be seen, is of very considerable practical importance.

If, for instance, the lodes grow richer down to a certain depth, and from that point grow leaner, and this depth is in any way associated with the character of the mine water, we should at once know to about what depth it may be advisable to explore a lode before abandoning it.

## SHALLOW WATERS AND DEEP WATERS.

Before discussing this possibility further, however, I want to lay down certain propositions regarding the character of the mine waters themselves, which are indeed practically interesting when one comes to consider such questions as the character of boiler water, the handling and separation of different parts of mine water, and the effect of it on the surface water.

1. My first proposition is that the waters from the copper mines are, for the first thousand feet or so, much more abundant than further down. The water from the deeper levels can be handled by a few trips with a bailer. Most of the water handled by pumps comes running down from near the surface. This is the experience of every mine, and so widely appreciated a fact that I need only to state it.

2. These waters are in chemical character closely allied to the surface waters of the region and entirely different from those further down. To prove this fact we may look at some of the analyses given in my annual report for 1903, pages 130-167, but I owe to the courtesy of various mine officials and the Dearborn Chemical company of Chicago the chance to examine very many others, mainly boiler analyses.

## CHARACTERISTICS OF SHALLOW WATER.

The essential characteristics of the shallow water are:

(a). The total mineral matter is low; always less than 300, normally a little less than 100, parts in a million—less than one-fifth of a pound in a ton of water or one-tenth of an ounce in a cubic foot. Consequently the specific weight, which may be determined readily by a physician's urinometer, is practically the same as that of pure water.

(b). Their softness is very different from the waters of the lower peninsula of Michigan. The amount of lime (calcium) is usually one which pure rain water will dissolve as carbonate—only 18 parts per million or 3 degrees of hardness. This is one of the special blessings of the copper country. The magnesium is still less—only about 4 parts per million.

(c). The chlorine is low and the presence of over 3 to 7 parts per million seems to be a sign of sewage or mine water contamination.

(d). The sodium is somewhat more in proportion, so that it cannot all be considered combined as common salt but in part as silicate of sodium (water glass) or carbonate or sulphate of soda.

(e). Dissolved silica is about 10 parts per million and dissolved iron usually about 1½ parts per million.

(f). Bicarbonates are not very abundant and carbon trioxide is normally not over 40 parts per million.

### CHARACTERISTICS OF DEEPER WATERS.

3. The deeper mine waters have an entirely different character and cannot be accounted for by any ordinary concentration or leaching of rock. Some of the essential points of difference are as follows:

(a). The chlorine is enormously greater and more than enough to combine with the sodium.

(b). The calcium is also enormously increased while the magnesium, silica, sulphates and carbonates are little if any greater. Potassium and bromine also occur in the deeper waters, which also contain a few grams per ton of copper, zinc and iron which must be considered combined as chlorides.

The low amount of sulphates is interesting but is explained when we note that Heath reports strontium chloride in one analysis, which would precipitate any large amount of sulphates in so strong a salt solution.

The occurrence of barium sulphate in the Calumet mine pointed out to me by Capt. Joseph Pollard, suggests that barium chloride may also have assisted in precipitating sulphates.

4. The transition from one kind of water to the other is relatively sharp. Just how sharp it is I do not yet know and observations on this line would be, I think, practically as well as scientifically interesting. A simple way of mapping the line would be to test the specific gravity with the urinometer, as I did at the Wolverine last summer. A mixture of the deeper waters seems almost at once to increase the weight of the water.

For instance Mr. Hartmann and I found in the Wolverine mine last summer the water in the eighth and thirteenth level crosscuts still soft and fresh, but at the seventeenth level it had already 2½ per cent. of salts largely calcium chloride. While it was somewhat salter at the bottom it did not increase in proportion to the sudden change between the thirteenth and seventeenth levels.

One advantage of mapping this line would be that from their corrosive character on pumps and boilers the lower waters should be handled quite differently from the other. Fortunately there is much less of them.

5. The deeper waters themselves vary in composition and contain more sodium at relatively shallow depths and more calcium chloride at greater depths.

## SOURCE OF ANALYZED WATERS.

Of the dozen or so analyses which I owe mainly to the kindness of various mining men, only two or three where I took the samples myself personally can be fairly considered as representing purely the lower water.

Generally these waters are the analyses of the sump of the mine or otherwise diluted and in the cases of mere dilution all constituents would be changed in practically the same ratio. This is pretty nearly true in comparing some of the analyses and is most nearly true if we compare the total solids, the chlorine and the bromine. It obviously will not be true in comparing those constituents which occur in the upper water any where as nearly abundantly as in the lower, such as magnesium, iron, alumina, silica, carbon trioxide and sulphuric anhydride.

When we come to the calcium and sodium, however, the quantities are so large in the lower water, compared with the upper, that we might expect that their proportions would be directly proportional to the dilution if the lower water were constant in comparison. The indications are, however, unmistakable and agree with the analyses of the Wolverine waters from the seventeenth level and the Tamarack water in the crosscut through from the forty-third level (although when we have to consider waters which are diluted from various depths we have to go into detailed discussion of each analyses which I cannot pretend to give here), that when the lower waters are first struck there is a greater proportion of sodium chloride than later.

### LOWER WATERS NOT FROM SURFACE.

The above are facts. Now what inferences may be drawn from them? We may, I think, safely assume that what I have called the upper waters are due to the downward percolation of the surface waters.

But I think it is impossible that a downward percolating water after having gone some hundreds of feet with only a small amount of chlorine should in the next 200 or 300 feet leach one hundred times as much out from the rocks which normally contain but a very small fraction of a per cent. of chlorine anyway.

And still more impossible is it that, after it has once obtained this sodium chloride, sodium should be precipitated and the calcium chloride leached instead. We might therefore pretty safely say that the lower waters have to a large extent not been derived from the surface.

We have then three suppositions left open to us: (a). That they have worked upward from the interior of the earth; (b). that they are residues of the ancient ocean into which these lava beds which form the Keweenawan formation originally flowed and in which sandstones and conglomerates were formed, or (c) they were vapors absorbed in these very lava flows.

That they were derived from fissures below seems to me very unlikely. Not only is their chemical character quite different from that of the average hot spring, but their universal distribution throughout the formation, even in the well at Freda, over on the lake shore, and the fact that the deeper waters of the iron mines (during the meeting of the Institute, August, 1906, a number of facts regarding salt water in the iron mines were given me) also seem to show a slight admixture of water of the same character—are very significant facts.

I have been and still am inclined to attribute these waters to some extent to the vapors in volcanic emanations directly associated with these great outbursts of lava. Especially have I thought that the few grams per ton of copper and iron chloride which they contain might be compared to the ferrous and other chlorides which are found around volcanoes which are now active.

But the wide extent of these waters in the Freda well, and in the iron country suggested that the original ocean of that time was of somewhat the same composition, and, as I have recently shown in an article before the geological society, if we take the composition of the present ocean and the changes produced in it year by year by the waters flowing into it, then some millions of years ago the ocean must have had very much the composition of these deep mine waters.

It is possible that the amounts of iron and copper chlorides which we find in them may have been dissolved from the lavas in the course of the decomposition which we know they have undergone. However that many be, in either case these waters will be essentially indigenous—not necessarily laid down in the rocks in which they are now found, or at the exact level, but nevertheless belonging to, laid down with, and characteristic of the Keweenawan formation as a whole.

ORIGINAL OF SODIUM BEARING MINERALS.

But how are we to account for the sodiferous character of the upper parts? A significant fact in this connection is the occurrence of the alkaline minerals such as analcite, mainly in the upper levels. The explanation suggested by Pumpelly may be applicable. He suggested that in the decomposition of the melaphyres the calcium minerals were first attacked and then at a later stage of decomposition the feldspars contained sodium and yielded these sodium bearing minerals, It is obviously easy to apply the same principle and suppose that the waters buried with the strata, and attacking and decomposing the same, attacked first the calcium bearing minerals forming calcium chloride and also the sodium minerals forming sodium chloride, or if they originally contained all their acid saturated with lime they may have thrown down some of that and taken up sodium in place.

But there is a significant factor in the solution of this problem which we must not overlook and that is the widespread occurrence of calcium carbonate. Whence came the carbonic acid?

It may also to some extent have been present among the vapors originally absorbed in the lava. But a very natural source for it is the waters working downward. If we take some of the water rich in calcium chloride and mix with some of the upper waters containing sodium carbonate, we should have sodium chloride formed and the calcium carbonate thrown down as calcite.

A very plausible explanation of the facts above stated would therefore be to suppose that as the original buried water was absorbed by the melaphyres or found its way by fissures up toward the surface in the lower parts of the Lake Superior basin under the lake, the fresh carbonated water from the surface worked in and followed it up, and slides or faults which traverse the formation would in many cases bring these waters over against one another; that then they reacted more or less upon each other, throwing down calcium carbonate and leaving some sodium chloride in solution.

### PROBABLE DISTRIBUTION OF COPPER.

Now what would be the probable distribution of the copper under this hypothesis? The surface waters for the first thousand or two thousand feet would unquestionably tend to carry the copper downward. For the suggestion of the secondary concentration of copper in our copper lodes I am indebted to F. W. Denton, No man is better qualified to judge, both by training and experience, than he in such matters.

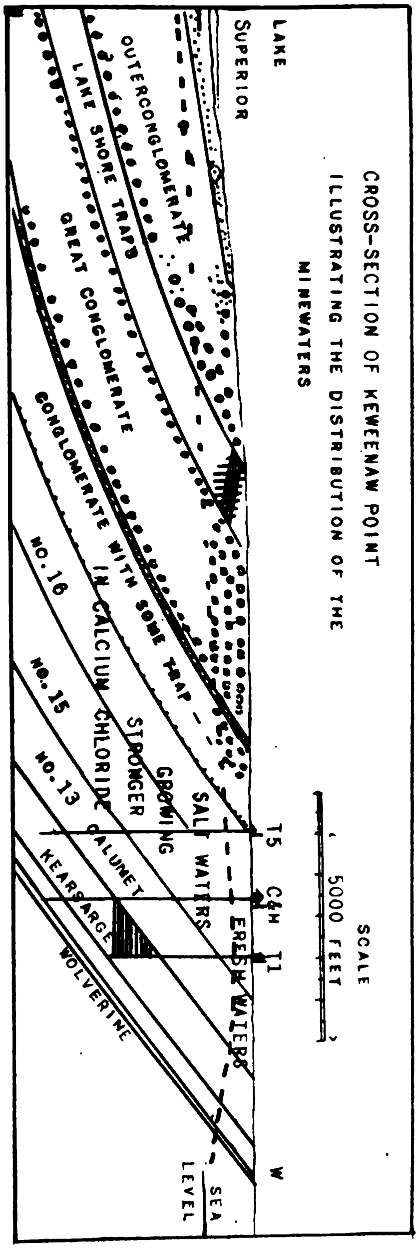
He believes that he has seen plain indications of the existence of surface fissures which lead to the impoverishment of the lode, and that the lodes tend in many cases to grow richer at least for a certain depth. So far as I know this theory is entirely original with Mr. Denton and the credit therefore is entirely due him and not to me, and I will not therefore enlarge upon facts which seem to substantiate it.

But the precipitation of copper certainly does not depend entirely upon the presence of these upper waters, for we find it extending in marked degree, though possibly not quite so richly, as far as the eye and hand of man have gone.

We must then assume that its collection is due to direct chemical and possibly electrolytic reaction of the deeper waters and the rocks in which they are contained. I see no reason why Pumpelly's original suggestion of the co-operation of the change from ferrous to ferric salts in the throwing down of the copper should not be still applicable.

A full discussion of the original minerals and how they may have been decomposed and the new minerals which accompanied the copper formed would not be fitting in this place. I may note that I have some rock salt crystals which Capt. Joseph Pollard gave me from the ninth level of the South Hecla and that there are signs that the deposition is associated with the decomposition of feldspar.

Calcium chloride and water are essentially the same as calcium hydrate and muriatic acid, and epidote can be derived from feldspar by adding calcium hydrate. Suffice it to say that they seem to me to fit admirably with the theory of reaction of upper waters containing sodium carbonates on rocks and on lower waters that contain chloride of calcium and the heavier metals like copper, though if we suppose the original rocks and emanations contain carbon dioxide or other carbon compounds, original or from weathering before their burial,


CROSS-SECTION OF KEWEENAW POINT
ILLUSTRATING THE DISTRIBUTION OF THE
MINEWATERS
SCALE
5000 FEET
LAKE
SUPERIOR
OUTERCONGLOMERATE
LAKE SHORE TRAPS
GREAT CONGLOMERATE
CONGLOMERATE WITH SOME TRAP
NO. 16
NO. 15
NO. 13
SALT WATERS
GROWING
STRONGER
IN CALCIUM CHLORIDE
CALUMET
KEARSARGE
WOLVERINE
T5
C&H
T1
W
FRESH WATERS
SEA
LEVEL

we do not need to assume the co-operation of the surface waters.

The point I wish now to urge is that while the upper type of waters in working down may, as Mr. Denton has suggested, tend to carry the copper with them, at the greatest depths the copper appears to exist in part dissolved and as yet unprecipitated, so that a belt just about at the beginning of the salt waters where they are extra rich in sodium chloride, as illustrated in a sketch which I give you, may be the richest.

This belt will of course not be regular. There are a number of cases beside that of the Franklin Junior, just now so conspicuous, where some enrichment in depth has been noted.

It also appears to be true that the rock grows less rich at extreme depths; but on these points it is not easy to speak positively, since the yield per fathom of rock broken or ton of rock hoisted depends mainly upon the price of copper, the cost of production and the skill and plan of selection. Replacing miners by less skilled men would tend to produce a lower yield and a lower cost of production; and a higher price would make it profitable to handle lower grade rock.

Thus the question as to the association of the richer rock with any particular type of mine water can only be solved by the average experience of those who are over the mines day after day, to whom I am now appealing for assistance.

And it must not be forgotten that there is plenty of copper in many cases in the upper zone of fresh waters. It must also be remembered that it is the water of the rock itself, not that following the shaft down, whose character should be studied.

Hoping that my friends in the copper country will assist me in studies along this interesting line of speculation, as they have in so many ways in the past.

# A HIGH DUTY AIR COMPRESSOR AT THE CHAMPION MINE.

By O. P. Hood, Houghton, Mich.

1. Large steam engines of exceptional performance have usually been connected with pumping machinery, the definite load removing some of the limitations imposed upon the designer of engines for general service. This characteristic of nearly uniform work performed per stroke is possessed also by machines for compressing air and the needs of a large mine are such as to require units for this purpose of large size. In the copper country of Michigan several such compressed air plants exceed 1,000 H. P. each and there is one about 5,000 H. P. Fuel is confined to the better grades of bituminous coal, worth in the hands of the fireman from $3 to $4 per ton so that economy in its use seems desirable. These facts have led some managers to install high duty machinery, and it is the purpose of this paper to report the results found in a test of a high duty air compressor installed at the Champion copper mine at Painesdale, Mich.

2. At the time of selection of this machinery Dr. L. L. Hubbard was general manager and Mr. F. W. O'Neil (Junior Member) was chief engineer. The Nordberg Manufacturing company of Milwaukee, Wis., proposed an engine designed to use steam at 300 pounds pressure equipped with a regenerative feed water heating system.

It was guaranteed that this engine should develop 180,000,000 foot pounds of work in the steam cylinders for each one million heat units used and should compress 9,000 cubic

(This paper was presented at the December meeting of the American Society of Mechanical Engineers.)

feet of air per minute to a pressure of 80 pounds gage, at 76 r. p. m. This guarantee was accompanied with a bonus and forfeit clause, the amount to depend upon the results of duty trials of the engine. Geary water tube boilers were installed and practically no difficulty was experienced with the installation until at pressures above 250 pounds, when there appeared boiler troubles which made it necessary to run the plant at the reduced pressure of 250 pounds. Under these conditions the original contract could not be carried out, but it was desired by Mr. F. W. Denton, general manager of the Copper Range Consolidated company, operating this mine, to discover the actual performance of this engine under the daily running conditions of reduced boiler and air pressure and at a speed about three-fourths of that contemplated in the guarantee but sufficient for the present maximum needs of the mine. The machine had been in commission for about 17 months, was in good order, and no changes of adjustments were made for the test. The test did not include the performance of the boilers.

3. The boiler plant consists of three "Geary" water tube boilers, each brick set, over 42 square feet of grate area.

4. Each boiler is hand fired, is credited with 2,068 square feet of heating surface and has 112 four-inch tubes 16′ long connecting front and rear water legs 11½″ wide. There are no baffles in the double drums. Gases pass through a Green economizer and motor driven fans to a short stack. Standard hydraulic pipe fittings are used.

## DESCRIPTION OF THE ENGINE.

5. The machine consists of four horizontal engines placed side by side, numbered for convenience 1, 2, 3 and 4. The high pressure engine, No. 1, has a cylinder diameter of 14.5″ with poppet valves connected to a governor, limiting the speed and also the maximum air pressure produced. No. 4 is the low pressure engine with a 54″ cylinder. The intermediate engines, No. 2 and No. 3, have cylinders 22″ and 38″ in diameter and all of these have Corliss valves and cut off adjust-

able, but not connected to the governor. The several cranks pass a dead center in the following order: No. 1 outer center, No. 3 inner, No. 4 inner, and No. 2 outer dead center.

6. The main shaft carries three fly wheels, the usual eccentrics for the Corliss valve motions and for the mechanically operated air valves. It also drives an offset crank on the high pressure end to actuate poppet valves, and a cranked shaft from the low pressure end to operate auxiliaries and the special valve in the low pressure heads. Below and between the cylinders reheating receivers are placed, each supplying steam to the cylinder, the jacketed heads, and the bodies of the next succeeding cylinder. Each head of the low pressure cylinder is provided with a rotating disk valve, driven from the main shaft, the function of which is to abstract steam during expansion. Steam is supplied through 90′ of 5″ double extra heavy pipe including a "Sweet" special separator 16″ in diameter and 42″ long.

### REHEATERS.

7. The high pressure cylinder is jacketed with steam coming from the drip of the main separator. This is led in turn through a reducing valve to the first reheater and a second reducing valve to the second and third reheaters, and then is delivered through a float trap to one of the series of feed water heaters.

### FEED WATER HEATING SYSTEM.

8. The feed heating system connected with the engine is divided into five approximately uniform steps with the object of gradually adding heat to the feed water by steam of progressively higher temperature which has done some work.

9. Condensation from the condenser, removed by the air pump, is raised to an open oil skimming tank by another pump.

10. An automatic float valve admits the feed to the preheater, where it gains in weight and temperature by contact with the exhaust from the low pressure cylinder. The feed is raised by a pump to an elevated heater where it meets steam

drawn during expansion through a special valve from the low pressure cylinder. By gravity the feed falls to a heater receiving the discharge from the low pressure jacket line which came from the third receiver. A second pump transfers the feed to a heater receiving the second intermediate jacket water and the discharge from the trap on the reheater line.

11. Pumped again to the last heater, the feed meets steam drawn through the first intermediate jacket from the first receiver. A fourth pump drawing from the last heater returns the feed, augmented in pressure, weight and temperature through an economizer to the boilers.

### AUXILIARIES.

12. The several auxiliary pumps are driven by oscillating levers actuated by a crank connection with the main engine shaft. These auxiliaries consist of an air pump for removing condensation from the surface condenser, a tank pump for elevating the condensation to the oil skimming tank, a pump for circulating water through the condenser, a double pump supplying water to the air cylinder jackets and spray intercooler, an oil pump for removing oil from the oil separator placed in the low pressure engine exhaust, four pumps transferring feed water from heater to heater and to the boiler, and a small air pump to charge air chambers on pump lines.

### AIR CYLINDERS.

13. Interposed between each steam cylinder and the guides is an air compressing cylinder. The first stage compression cylinders are attached to high and low pressure engines and the second stage cylinders are attached to the intermediate engines. All air cylinders have Corliss valves operated from eccentrics, the cylinders and heads are water jacketed, and between the two stages air is cooled in a spray intercooler. Air is admitted to the first stage cylinders through short lengths of pipe from without the building and is discharged to a receiver before entering the distributing system.

### AUXILIARY PIPING.

14. Air chambers on all pump lines are piped to receive compressed air when needed. All heaters are connected by small piping to the condenser to remove air which occasionally traps in them. All water jackets about air cylinders are tapped at the highest point by a system of piping, leading to the intercooler and are continuously bled to prevent pocketing of air. Steam taken from receivers to jackets passes oil separators dripped into the receivers which drain through blow off pipes. Oil for lubrication is supplied through a system of piping. Electrical connections are provided for indicators at each cylinder end.

### RELATION OF PARTS.

15. The whole machine occupies a space 45x56 feet in one end of a building, there being on the same level with the four engines the intercooler and skimming tank, while below the floor are receivers, governor mechanism, auxiliary pumps, oil separator, and traps. The condenser and preheater extend from the basement through and above the main floor.

### CONCERNING TESTS.

16. The feed water leaving the last pump under boiler pressure and at a temperature of 334.5 degrees was cooled by throttling through cast radiators immersed in cold water and delivered to weighing tanks holding about 3,000 pounds each.

17. The duty was determined in a run of ten hours on March 8, by weighing the cooled water from the heaters and taking indicator cards from the eight steam and air cylinders with sixteen indicators electrically connected so that simultaneous cards were obtained. To determine the distribution of heat a similar test of five hours' duration was run on March 17, when the water coming from the condenser was weighed, as well as that from the heaters, to determine the per cent. added in the heaters. To determine what proportion of this addition was abstracted from each receiver it was necessary to

adopt some method which would determine the quantity without taking anything from the system or interfering with the flow to any extent. Into each line sending wet steam to either reheater or feed heater a large separator was placed, the outlet being provided with a throttling calorimeter.

18. A glass on the side of the separator showed the rate at which water accumulated. When a small amount had accumulated it was allowed to continue its normal journey to the heater by discharging through a three-way-cock.

19. The quality of the very wet steam supplied to each place was in this way determined and the weight flowing to each heater computed from the observed temperature rise in feed heaters. This method produced no disturbance of temperatures in the feed heaters, but the numerous calorimetric determinations together with the cumulative errors of such a method make the results approximate.

PERSONAL.

20. To Mr. F. W. Denton, general manager of the Copper Range Consolidated company, thanks are due for permission to publish these results and for interest shown in the work.

21. For aid in many ways in the preparation for and conduct of these several tests, acknowledgment should be made of valuable services rendered by Mr. R. R. Seeber, chief engineer, Champion Copper company; Mr. R. H. Corbett, (member), representative of the Nordberg Manufacturing company; assistant professor, George L. Christensen, Michigan College of Mines; Mr. Wm. Richards, master mechanic; Mr. W. Stevens, foreman; Engineers D. McLeod and D. Toms, students of the Michigan College of Mines, and others who acted as observers, and to Mr. A. G. Andrew, Jr., who was employed in working up results and making drawings.

EXHIBITS.

22. Fig. 11 shows a diagrammatic section through the cylinders and heaters illustrating the path of the steam and feed

water and indicating the points of observation involved in this test. The numbers correspond to similar numbers in the several logs.

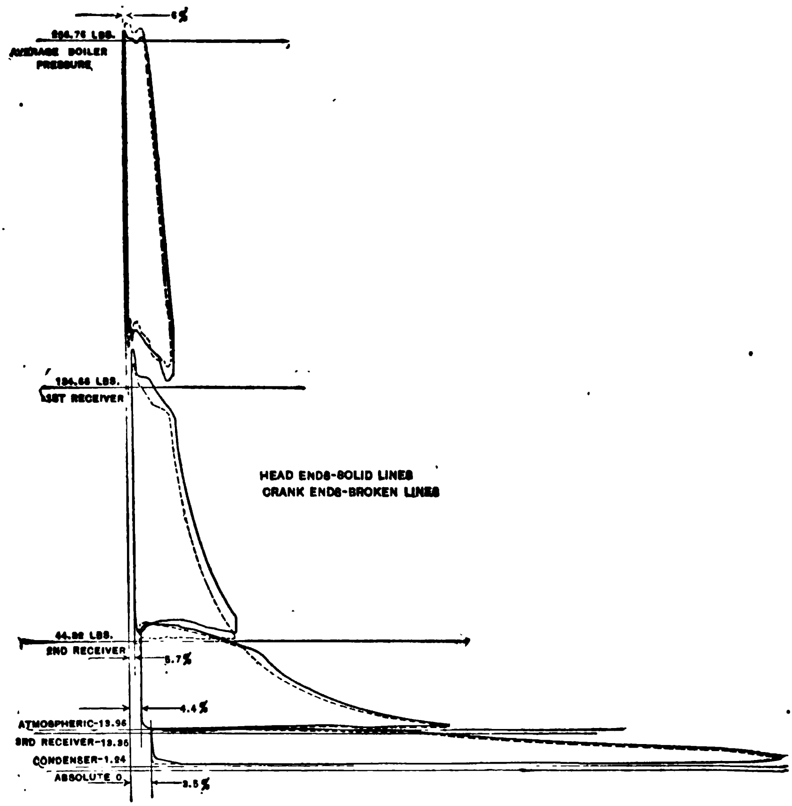



FIG. 14 COMBINED SIMULTANEOUS CARDS FROM HEAD AND CRANK ENDS OF STEAM CYLINDERS.
Vertical Scale 1″=15 lbs.

DIMENSIONS.

| | | | | |
|---|---|---|---|---|
| Number of cylinder ..... | 1 | 2 | 3 | 4 |
| Diameter ........ ...... | 14.52″ | 22.01″ | 38.00″ | 54.00″ |
| Length of stroke ....... | 48.00″ | 48.00″ | 48.00″ | 48.00″ |
| Diam. of piston rod crank end ...... ......... | $3\frac{3}{8}$″ | $3\frac{3}{8}$″ | $3\frac{3}{8}$″ | $3\frac{3}{8}$″ |
| Net area of piston head end ...... .......... | 165.58″ | 380.48″ | 1134.10″ | 2290.20″ |
| crank end .......... | 156.64″ | 371.54″ | 1125.16″ | 2281.20″ |
| Clearance ........ .... | 6.0% | 5.7% | 4.4% | 3.5% |

| | | | | |
|---|---|---|---|---|
| Cylinder volume head end | 7948 | 18,263 | 54,437 | 109,900 |
| crank end | 7519 | 17,833 | 54,008 | 109,500 |
| Vol. plus clearance head end | 8425 | 19,300 | 56,830 | 113,780 |
| crank end | 7996 | 18,870 | 56,400 | 113,350 |
| Cylinder ratios | 1.000 | 2.330 | 7.01 | 14.19 |
| Horse power const. head end | 1.143 | 2.626 | 7.828 | 15.808 |
| crank end | 1.081 | 2.564 | 7.766 | 15.746 |

| | | | | |
|---|---|---|---|---|
| Number of air cylinder | 1 | 2 | 3 | 4 |
| Diameter | 37.22″ | 23.07″ | 23.02″ | 36.74″ |
| Length of stroke | 48.00″ | 48.00″ | 48.00″ | 48.00″ |
| Diam. of piston rod head end | 3⅜″ | 3⅜″ | 3⅜″ | 3⅜″ |
| crank end | 3⅝″ | 3⅝″ | 3⅝″ | 3⅝″ |
| Net area of piston head end square inch | 1079.40 | 409.25 | 407.43 | 1051.20 |
| crank end | 1078.00 | 407.87 | 406.06 | 1049.80 |
| Clearance .......head end | 2.65% | 1.92% | 1.92% | 2.65% |
| crank end | 2.57% | 1.74% | 1.74% | 2.57% |
| Air cylinder ratio | 1 to 2.61 | | | |
| Air pump | | | 20″ | 12 31-32″ |
| Circulating pump | | | 10⅞″ | 19⅛″ |
| Tank pump | | | 5″ | 13″ |
| Intercooler pumps | | | 5½″ | 11 13-16″ |
| All feed pumps | | | 6″ | 7 5-16″ |

Main steam pipe 5″ double extra heavy condenser 2700 sq. ft. of cooling surface.

## TOTAL QUANTITIES, TIME, ETC.

| | |
|---|---|
| Duration of test | 10 hrs. |
| Water delivered from last heater as boiler feed | 117,950 lbs. |
| Moisture in the steam near the throttle | 5.74% |
| Factor of correction for quality of steam | 94.26 |
| Total dry steam used | 111,180 lbs. |

## HOURLY QUANTITIES.

| | |
|---|---|
| Feed water per hour | 11,795 lbs. |
| Dry steam per hour | 11,118 lbs. |

## PRESSURES, TEMPERATURES, ETC.

| | |
|---|---|
| Steam gage pressure near throttle | 242.80 lbs. |
| Barometric pressure | 28.50 ins. |
| Pressure in receiver First | 120.70 lbs. |
| Second | 30.80 lbs. |
| Third | —1.24 ins. |
| Vacuum in condenser | 25.95 ins. |
| Absolute pressure in condenser | 1.25 lbs. |
| Pressure in steam jackets No. 1 | 242.00 lbs. |
| No. 2 | 120.00 lbs. |
| No. 3 | 30.00 lbs. |
| No. 4 | —1.24 ins. |
| Pressure in heaters No. 1 | 209.00 lbs. |
| No. 2 | 104.00 lbs. |
| No. 3 | 73.00 lbs. |
| Quality of steam in receivers No. 1 | 100% |
| No. 2 Superheat | 17° |
| No. 3 Superheat | 9° |

### TEMPERATURES.

| | |
|---|---|
| Temperature of steam fed to No. 1 engine | 403.4° |
| Temperature of steam leaving receiver No. 1 | 351.2° |
| Temperature of steam leaving receiver No. 2 | 291.2° |
| Temperature of steam leaving receiver No. 3 | 216.0° |
| Temperature of exhaust entering preheater | 114.9° |
| Temperature corresponding to condenser pressure | 109.6° |
| Temperature of water fed to preheater | 92.5° |
| Temperature of water fed to heater No. 1 | 114.3° |
| Temperature of water fed to heater No. 2 | 173.1° |
| Temperature of water fed to heater No. 3 | 202.0° |
| Temperature of water fed to heater No. 4 | 269.7° |
| Temperature of water leaving heater No. 4 as boiler feed | 334.5° |

### HEAT QUANTITIES.

| | |
|---|---|
| Heat units per pound of steam, pressure 256.8 abs | 1204.98 B. T. U. |
| Heat units per pound of steam supplied to engine | 1157.46 B. T. U. |
| Heat units per pound of feed returned by engine | 305.14 B. T. U. |
| Heat units per pound of steam charged to engine | 852.32 B. T. U. |

### SPEED.

| | |
|---|---|
| Total revolutions in ten hours | 34,167 |
| Revolutions per minute | 56.945 |
| Piston speed in feet per minute | 455.5 |
| Speed compared to contract speed | 74% |

### POWER.

| Cylinder | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Indicated horse power developed in steam cylinders | 181.47 | 256.96 | 275.71 | 275.56 |
| Indicated horse power used in the air cylinders | 220.04 | 222.12 | 226.20 | 214.84 |

| | |
|---|---|
| Total indicated horse power, steam cylinders | 989.7 H. P. |
| Total horse power used in air cylinders | 883.2 H. P. |
| Total indicated horse power of auxiliaries | 11.0 H. P. |
| Horse power representing friction of the machine | 95.5 H. P. |
| Per cent of friction | 9.65% |
| Mechanical efficiency engine and compressor | 90.35% |

### STANDARD EFFICIENCY RESULTS.

| | |
|---|---|
| Heat consumed by engine per hour per I. H. P. | 10,157 B. T. U. |
| Heat consumed by engine per hour per B. H. P. | 11,382 B. T. U. |
| Equivalent standard coal consumption per hour assuming calorfic value of coal such that 10,000 B. T. U. are imparted to the boiler per pound coal per I. H. P. | 1.016 lbs. |
| coal per B. H. P. | 1.138 lbs. |
| Dry steam per I. H. P. per hour | 11.23 lbs. |
| Dry steam per B. H. P. per hour | 12.58 lbs. |
| Heat units consumed per minute per I. H. P. | 169.29 B. T. U. |
| Heat units consumed per minute per B. H. P. | 189.70 B. T. U. |
| Efficiency of theoretical Carnot cycle between the temperature of incoming steam and the temperature corresponding to pressure in the condenser | 34.0 % |
| Actual heat efficiency attained by this engine | 25.05% |
| Relative efficiency compared with Carnot cycle | 73.69% |
| Relative efficiency compared with Rankine cycle | 88.2 % |

### DUTY.

Duty in foot-pounds of work developed per million heat units supplied to the engine......194,930,000-foot-pounds

This engine establishes a new low record for the heat consumed per hour per I. H. P., being 9% lower than that used by the Wildwood pumping engine reported in 1900.

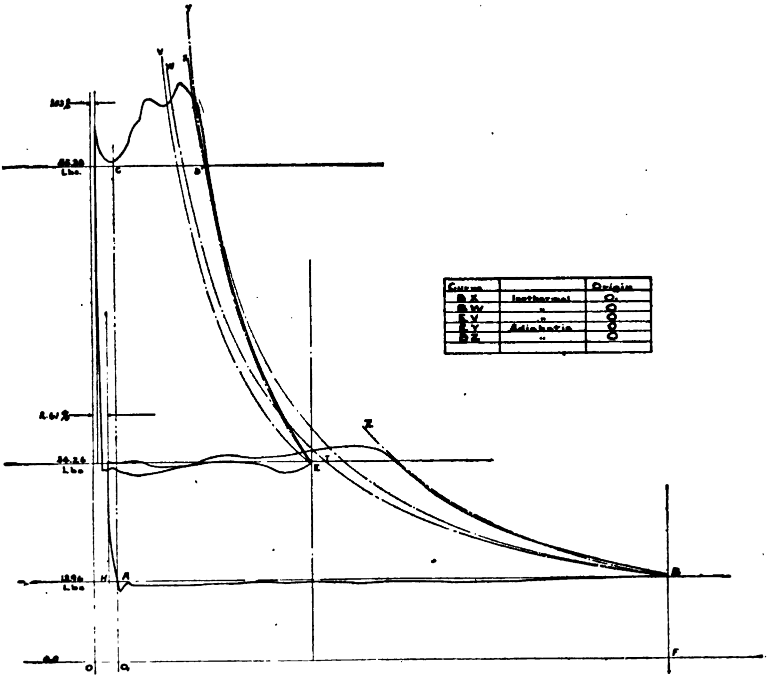


FIG. 16 COMBINED COMPOSITE AIR CARDS WITH REFERENCE CURVES.
Vertical Scale 1″=10 lbs.

23. The path followed by the steam through the several devices is shown in Fig. 11, while Fig. 12 shows in a diagrammatic way the flow of heat. The heat used by the engine per minute was carried by 196,578 pounds of wet steam of quality 94.26% having a value of 1157.46 heat units per pound, which weight was returned to the boilers with a heat content of 305.14 heat units, making a net expenditure of 852.32 B. T. U. per pound or a total of 167,547 B. T. U. per minute.

24. The distribution of this heat is approximated in Fig. 12. The test of the 17th showed the weight coming from the

condenser, when corrected for the difference in the two tests in the heat added in the No. 4 heater, to be 69.2% of that charged to the engine. Beginning with this quantity of 136 pounds per minute and making the additions of weight necessary to raise the feed water to the temperature observed in each heater by the addition of wet steam of the quality determined by the several calorimeters, the computed weight going from No. 4 heater would be 8.3 pounds in excess of the known weighed amount, although the additions of heat by this computation would be in excess only 595 B. T. U. in 51,733.

25. An adjustment of the several computed weight additions in each heater was, therefore, necessary and each was multiplied by 88% on the assumption that the cumulative errors were equally distributed. This gives the following distribution of weight used per minute:

| | Pounds |
|---|---|
| Steam fed to engine per minute (weighed) | 196.5 |
| Steam sent to reheater line | 20.2 |
| Steam sent through No. 1 cylinder | 176.3 |
| Steam taken from No. 1 receiver | 14.9 |
| Steam sent through No. 2 cylinder | 161.4 |
| Steam taken from No. 2 receiver | 11.0 |
| Steam sent through No. 3 cylinder | 150.4 |
| Steam taken from No. 3 receiver | 4.9 |
| Steam sent to No. 4 cylinder | 145.5 |
| Steam taken from No. 4 cylinder during expansion | 7.3 |
| Steam condensed in the preheater | 2.2 |
| Steam sent through condenser (weighed) | 136.0 |

26. Those adjusted weights when applied to the quantity in each feed water heater are as follows:

| | Pounds |
|---|---|
| Feed water sent to preheater per minute | 136.0 |
| Added in the preheater | 2.2 |
| Feed water sent to No. 1 heater | 138.2 |
| Added in No. 1 heater from No. 4 cylinder | 7.3 |
| Feed water sent to No. 2 heater | 145.5 |
| Added in No. 2 heater from No. 4 jacket | 4.9 |
| Feed water sent to No. 3 heater | 150.4 |
| Added in No. 3 heater from No. 3 jacket | 31.2 |
| Feed water sent to No. 4 heater | 181.6 |
| Added in No. 4 heater from No. 2 jacket | 14.9 |
| Feed water sent to boilers (weighed) | 196.5 |

27. The heat given up to each jacket was computed from the quality determinations on each side of the jacket and the weight flowing to the several heaters.

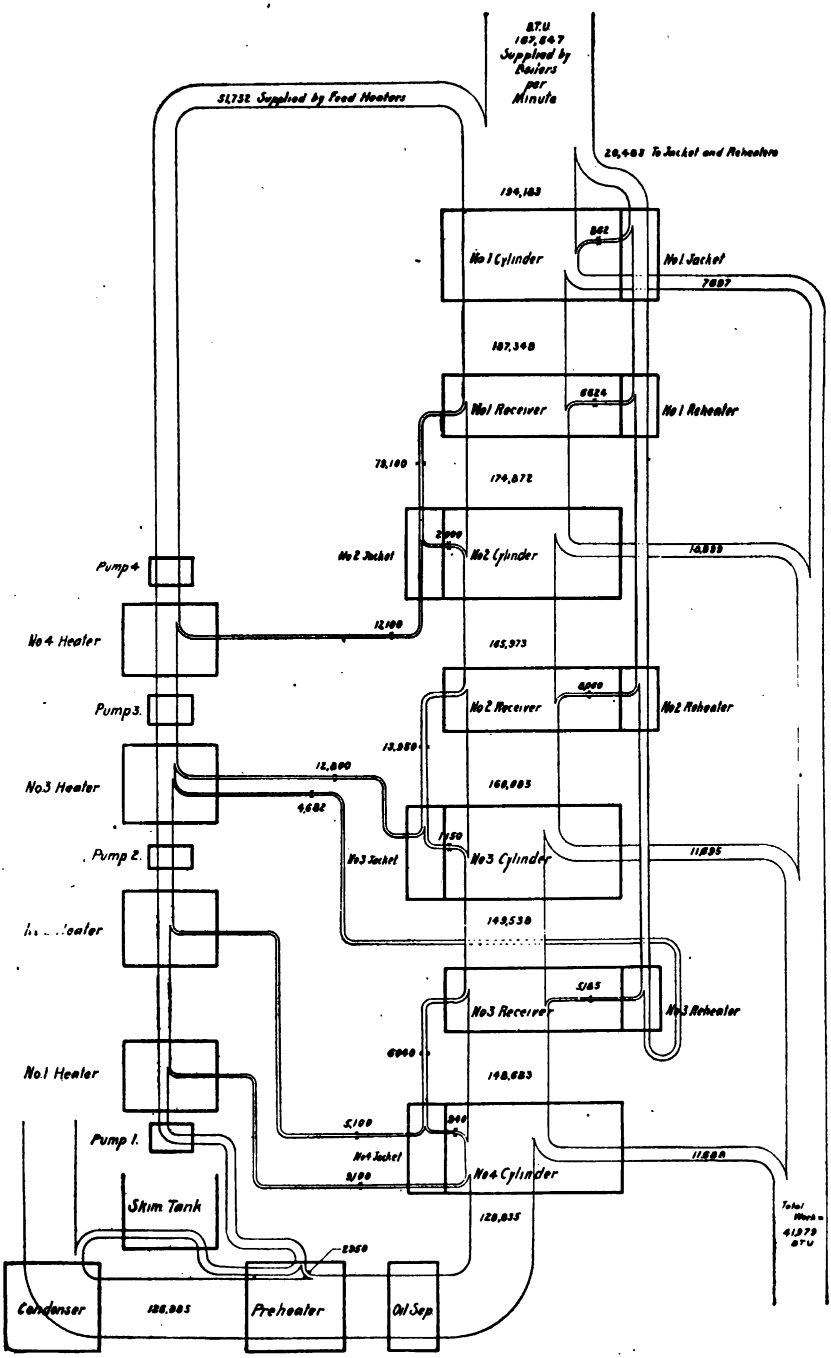



FIG. 12 DIAGRAMMATIC REPRESENTATION OF FLOW OF HEAT THROUGH THE ENGINE. (Approximate Distribution).

28. No measurement of the radiation from the machine was attempted because of the complication incident to maintaining the several pressures required and because the distribution of perhaps 2% of the total heat used through the numerous devices was hardly warranted.

RESULTS FROM THE AIR COMPRESSING CYLINDERS.

33. The air compressing is accomplished in two low pressure and two high pressure cylinders, each double acting. The four cards showing the performance of the same function were superimposed and a composite was drawn representing the mean condition shown in Fig. 16.

34. The volumetric efficiency is 98.43% and would require a speed of 77.3 r. p. m. to deliver the required 9000 cu. ft. of air per minute. The actual H. P. shown by the air cards is 883.2 H. P. while the same weight of air compressed isothermally would require but 731.3 H. P., showing an efficiency of the two stage compression compared with isothermal of 82.8%.

35. The temperatures of air and jacket water were as follows:

| | Low. | Pres. | High | Pres. |
|---|---|---|---|---|
| Cylinder | 4 | 1 | 2 | 3 |
| Temperature of air enterting | 31 | 31 | 53.2 | 52.8 |
| Temperature of air leaving | 188.2 | 183.7 | 224.6 | 227.0 |
| Temperature difference | 157.2 | 152.7 | 171.4 | 174.2 |
| Temperature of water entering jacket | 42.8 | 58.2 | 73.0 | 82.8 |
| Temperature of water leaving jacket | 58.2 | 73.0 | 82.8 | 96.4 |
| Temperature difference | 15.4 | 14.8 | 9.8 | 13.6 |

36. The water was supplied to the several jackets in series through a shunt circuit from a line supplying water to the intercooler.

# PAST OFFICERS.

## PRESIDENTS.

| | |
|---|---|
| Nelson P. Hulst | 1893 |
| J. Parke Channing | 1894 |
| John Duncan | 1895 |
| William G. Mather | 1896 |
| William Kelly | 1898 |
| Graham Pope | 1900 |
| W. J. Olcott | 1901 |
| Walter Fitch | 1902 |
| George H. Abeel | 1903 |
| O. C. Davidson | 1904 |
| James MacNaughton | 1905 |

(No meetings were held in 1897 and 1899.)

## VICE-PRESIDENTS.

1893.

John T. Jones.
F. P. Mills.
J. Parke Channing.
Graham Pope.
M. W. Burt.

1894.

John T. Jones.
F. P. Mills.
R. A. Parker.
Graham Pope.
W. J. Olcott.

1895.

F. McM. Stanton.
Geo. A. Newett.
R. A. Parker.
Per Larsson.
W. J. Olcott.

1896.

F. McM. Stanton.
Geo. A. Newett.
J. F. Armstrong.
Per Larsson.
Geo. H. Abeel.

1898.

E. F. Brown.
James B. Cooper.
Ed Ball.
Walter Fitch.
Geo. H. Abeel.

1900.

O. C. Davidson.
T. F. Cole.
M. M. Duncan.
J. H. McLean.
F. W. Denton.

1901.

J. H. McLean.
M. M. Duncan.
Nelson P. Hulst.
F. W. Denton.
William Kelly.

1902.

William Kelly.
Nelson P. Hulst.
Fred Smith.
H. F. Ellard.
Wm. H. Johnston.

1903.

H. F. Ellard.
Fred Smith
James B. Cooper.
Wm. H. Johnston.
John H. McLean.

1904.

M. M. Duncan.
Fred M. Prescott.
F. W. McNair.
John H. McLean.
James B. Cooper.

1905.

| | | |
|---|---|---|
| M. M. Duncan. | | J. M. Longyear. |
| Fred M. Prescott. | F. W. McNair. | F. W. Denton. |

MANAGERS.

| | | |
|---|---|---|
| | 1893. | |
| John Duncan. | | James MacNaughton. |
| Walter Fitch. | William Kelly. | Charles Munger. |
| | 1894. | |
| Walter Fitch. | | C. M. Boss. |
| John Duncan. | M. E. Wadsworth. | O. C. Davidson. |
| | 1895. | |
| F. P. Mills. | | C. M. Boss. |
| Ed. Ball. | M. E. Wadsworth. | O. C. Davidson. |
| | 1896. | |
| F. P. Mills. | | Graham Pope. |
| Ed. Ball. | C. H. Munger. | William Kelly. |
| | 1898. | |
| M. M. Duncan. | | Graham Pope. |
| J. D. Gilchrist. | T. F. Cole. | O. C. Davidson. |
| | 1900. | |
| E. F. Brown. | | Walter Fitch. |
| Ed. Ball. | James B. Cooper. | George H. Abeel. |
| | 1901. | |
| James B. Cooper. | | James Clancey. |
| James MacNaughton. | (One Vacancy.) | J. L. Greatsinger. |
| | 1902. | |
| James Clancey. | | Graham Pope. |
| J. L. Greatsinger. | Amos Shephard. | T. F. Cole. |
| | 1903. | |
| Graham Pope. | | T. F. Cole. |
| Amos Shephard. | Wm. J. Richards. | John McDowell. |
| | 1904. | |
| John McDowell. | | William Kelly. |
| Wm. J. Richards. | John C. Greenway. | H. B. Sturtevant. |
| | 1905. | |
| John C. Greenway. | | William Kelly. |
| H. B. Sturtevant. | Felix A. Vogel. | J. R. Thompson. |

TREASURERS.

C. M. Boss....................1893
A. C. Lane....................1894
Geo. D. Swift....................1895-1896
A. J. Yungbluth....................1898-1900
Geo. H. Abeel....................1901-1902
E. W. Hopkins....................1903-....

SECRETARIES.

F. W. Denton....................1893-1896
F. W. Denton and F. W. Sperr....................1898
F. W. Sperr....................1900
A. J. Yungbluth....................1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

American Institute of Mining Engineers, 99 John St., New York City.

Canadian Mining Institute, Ottawa.

American Society of Civil Engineers, 220 W. 57th St., New York City.

Institution of Mining Engineers, Neville Hall, Newcastle-upon-Tyne.

Massachusetts Institute of Technology, Boston, Mass.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

Western Society of Engineers, 1734-41 Monadnock, Blk., Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Society of Civil Engineers, Montreal.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

State Bureau of Mines, Colorado, Denver, Colo.

Stahl und Eisen, Dusseldorf, Germany, Jacobistrasse 5.

Reports of the U. S. Geological Survey, Washington, D. C.

Geological Survey of New South Wales, Sydney, N. S. W.

Geological Survey of Ohio State University, Columbus, Ohio.